MINERALS YEARBOOK

1964

Volume I of Four Volumes

METALS AND MINERALS
(Except Fuels)

U.S. DEPARTMENT OF THE INTERIOR
March 3, 1849

Prepared by staff of the
BUREAU OF MINES

UNITED STATES DEPARTMENT OF THE INTERIOR • Stewart L. Udall, Secretary

BUREAU OF MINES • Frank C. Memmott, Acting Director

Created in 1849, the Department of the Interior—a Department of Conservation—is concerned with the management, conservation, and development of the Nation's water, fish, wildlife, mineral, forest, and park and recreational resources. It also has major responsibilities for Indian and Territorial affairs.

As the Nation's principal conservation agency, the Department works to assure that nonrenewable resources are developed and used wisely, that park and recreational resources are conserved for the future, and that renewable resources make their full contribution to the progress, prosperity, and security of the United States—now and in the future.

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FOREWORD

The 1964 MINERALS YEARBOOK is the second annual review to be presented in four volumes, the fourth volume portraying international mineral industry events on a country-by-country basis. The general content of the four-volume edition follows:

Volume I, *Metals and Minerals* (*Except Fuels*), contains chapters on metal and nonmetal mineral commodities except mineral fuels. In addition, it includes a chapter reviewing these mineral industries, a statistical summary, and chapters on mining and metallurgical technology, employment and injuries, and technologic trends.

Volume II, *Mineral Fuels*, contains a chapter on each mineral fuel and on such related products as helium, carbon black, peat, coke and coal chemicals, and natural gas liquids. Also included are data on employment and injuries in the fuel industries and a mineral-fuels review summarizing recent economic and technological developments.

Volume III, *Area Reports: Domestic*, contains chapters covering each of the 50 States, the U.S. island possessions in the Pacific Ocean, the Commonwealth of Puerto Rico, the U.S. island possessions in the Caribbean Sea, and the Canal Zone. Volume III also has a statistical summary chapter, identical with that in Volume I, and a chapter on employment and injuries.

Volume IV, *Area Reports: International*, contains chapters presenting the latest available mineral statistics for more than 130 foreign countries and areas. A separate chapter reviews minerals in the world economy. In its first year—1963—the international review volume presented considerable background information on the mineral resources of individual countries, which has been omitted from the 1964 issue. Thus the length of Volume IV has been greatly reduced.

The Bureau of Mines' continuous effort to enhance the Yearbook's value to its wide readership can be aided by constructive comments and suggestions of its users. Such comment is particularly invited during the formative years of the new International review volume.

Frank C. Memmott, *Acting Director*

ACKNOWLEDGMENTS

The staff of the Division of Minerals prepared this volume except for the three review chapters and that on Employment and Injuries. The preparation and the coordination of chapters with those in other volumes was under the general direction of Paul Yopes, Assistant to the Chief, Division of Minerals. The manuscripts upon which the volume was based were reviewed by a staff under the direction of Kathleen J. D'Amico to insure statistical consistency among the tables, figures, and text between this volume and other volumes, and between this volume and those for former years.

The statistical data of the U.S. mineral industry presented have been collected and compiled by the staff of the Division of Statistics under the direction of Paul W. Icke, Acting Chief, assisted by Albert D. McMahon, Chief, Section of Nonferrous Metals; and Isaac E. Weber, Chief, Section of Ferrous Metals—Nonmetals.

World production and foreign trade tables were compiled under the direction of Berenice B. Mitchell, Supervisory Statistical Officer, Division of International Activities, from many sources including data from the Foreign Service, U.S. Department of State.

Figures in the Minerals Yearbook are based largely upon information supplied by mineral producers, processors, and users, and acknowledgment is made of this indispensable cooperation given by industry. Information obtained from individuals through confidential surveys has been grouped to provide statistical aggregates. Data on individual producers are presented only if available from published or other nonconfidential sources, or when permission of the individuals concerned has been granted.

The Bureau of Mines has been assisted in collecting mine-production data and the supporting information appearing in the Minerals Yearbook by more than 40 cooperating State agencies. These organizations are listed in the acknowledgment section of Volume III.

CHARLES W. MERRILL,
Chief, Division of Minerals

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Review of the Mineral Industries[1]

(Metals and Nonmetals Except Fuels)

By Kung-Lee Wang[2] and Edward E. Johnson[2]

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SUSTAINED growth characterized the U.S. economy in 1964. Many new peaks were achieved in production, sales, employment, employee earnings, and business profits. At the end of 1964, the economy had experienced 4 years of uninterrupted expansion, and the greatest net gains in output for all postwar cyclical advances had been registered. There were no indications of the various weaknesses which have previously characterized advanced stages of business expansion. Both gross national product (GNP) and national income were 6.7 percent higher than in 1963. In 1964 GNP totaled $628.7 billion, a gain of $39.2 billion over the 1963 figure. On an overall basis, prices rose 1.75 percent in 1964. The real volume of output of goods and services (GNP in constant dollars) increased by 5.0 percent in 1964; this was more than the 3.8-percent gain in 1963 but less than the 6.6 percent gain in 1962. The 1964 output gain also exceeded the average 3.7 percent annual increase for the postwar period.

Congress authorized a two-stage tax reduction designed to further stimulate economic growth and employment. The tax cut favorably affected the 1964 economy in the following ways: By helping to boost personal income, corporate profits, and industrial production; by accelerating the pace of consumer spending and business capital expansion; and by increasing employment, thereby reducing unemployment to 5 percent. Three major problems remained unsolved. These were unemployment of 3.7 million persons, poverty conditions among more than 30 million persons in the United States, including those in many mining areas, and disequilibrium in the U.S. international balance of payments. For only the latter did the prospect of improvement appear good.

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[1] Some fuels are covered in this chapter but only where specifically indicated and in general where mining-industry data were not available for both nonfuels and fuels components.
[2] Economist.

During 1964, industrial production reached a new peak. Although mining production also reached a new high, current and constant dollar value of mineral production lagged slightly behind the buoyant growth of the total economy. Percentage gains in output of primary metals, especially iron and steel products, were more than double that of total industrial production. The U.S. production of 127 million tons of steel in 1964 exceeded the 1955 record by 9 million tons and caused the steel-associated minerals group to attain a record high. Nonferrous metals and products output also registered new highs but with less spectacular gains than in 1963. These gains resulted in a notable increase in nonferrous mining. As a result of the continuing high level of highway and building construction and a strengthening demand for chemical and fertilizer minerals, record output was achieved for nonmetals other than fuels. The outputs of all energy minerals also increased.

Net supply of minerals, metals, and fuels generally gained, and exports and imports also increased. Imports continued to be an important source of new supply. Secondary production provided a larger percentage of U.S. metals supply. Consumption of all minerals and processed minerals products continued the upward trend of the past few years and was generally greater than in 1963. The consumption of ferrous metals and ores made the greatest overall gains in 1964, whereas consumption of nonferrous metals and ores and nonmetals rose modestly.

Physical stocks declined notably in 1964. This change was principally attributed to depletion of stocks of steel-associated minerals, nonferrous metal ores and sulfur.

Labor productivity in mining continued its gradual upward trend with a notable increase in the mining of crude iron ore. The small increase of employment in metals and nonfuel minerals mining compensated for the decline of employment in coal mining, and resulted in no change for overall employment in mining industries in 1964. Employment rose more in mineral manufacturing than in any other industry. Wages and salaries in the mining industry including fuels continued the upward trend begun in 1961. Once more employment and earnings in mining lagged behind the totals for all industries and manufacturing.

Average unit mine value and implicit unit value of all minerals rose slightly but less than the overall price increase. Prices of metal scrap and primary nonferrous metals gained substantially, whereas prices of chemical and fertilizer minerals increased moderately. Cost of machinery and supplies used in mining increased mildly while the cost of fuels, electric energy, and labor declined.

Income originating from all mining industries rose modestly, reversing the downward trend that began in 1961; however the increase was less than those of all industries and manufacturing. The annual profit rates of the mineral manufacturing industries made notable gains in 1964. A substantial improvement was reported for the profit rate of the primary metal industry, which outgained all manufacturing.

An increase was noted in capital expenditures for new plant and equipment in the mineral industries, especially in the iron and steel industry. However the increase was less than that reported for all manufacturing. The value of U.S. private investment in foreign mining and smelting industries increased slightly but was below that for all industries. As in the past, U.S. mining companies abroad relied primarily on foreign internally generated funds to finance capital expenditures and operations.

Research and development expenditures in the mining industry rose very modestly and increases continued to be minor in comparison with those of other industries.

Activity under the Defense Mobilization Program was highlighted by the extension of the Defense Production Act for 2 years until June 30, 1966, and new stockpile objectives for conventional war and disposal programs were put into effect.

The total value of U.S. foreign trade in nonfuel minerals and related products rose in 1964, as did the total value of U.S. mineral and related products imports. Imports of metal ores and manufactured nonmetals increased moderately, metal imports rose substantially, and crude nonmetals imports declined. The total value of U.S. mineral and related products exports gained. Exports of metallic ores, metals, and crude nonmetallic minerals increased substantially while those of manufactured nonmetallic minerals rose to a lesser extent.

The U.S. Tariff Commission reported that under the Antidumping Act of 1921 three domestic industries—chromic acid, steel reinforcing bars, and carbon steel bars and shapes—were likely to be injured by foreign imports to the United States at less than fair value. The Sixth Round of Trade Negotiations under the auspices of the General Agreement on Tariffs and Trade—widely known as the Kennedy Round—began in November 1964. The outcome of the Kennedy Round negotiations could have significant influence on the development of U.S. mineral and related industries.

Minerals and related commodities again made the greatest use of U.S. rail and water transportation. The movement of minerals and related commodities supplied about 60 percent of the total rail traffic and over 80 percent of the total water traffic. Mineral fuels (principally coal), nonmetallic minerals, and metals and metal ores accounted for about 31 percent, 16 percent, and 13 percent, respectively, of total rail shipments. Mineral fuels shipments accounted for 60 percent of total water transportation, nonmetals for 12 percent, and metals and ores for 8 percent. Trucking continued to be the principal transportation method for construction materials. Of the total shipments of sand and gravel, crushed stone, portland cement, and blast furnace slag, 90 percent, 70 percent, 66 percent, and 74 percent, respectively, were by truck.

The world economy continued to expand and world mineral industries had another good growth year. World production of both metal and nonmetal mineral products rose notably, although the U.S. gains were less than those of the rest of the world. The United States continued to be the leading consumer and an important producer of many minerals and related products. World mineral consumption made excellent gains in 1964, surpassing those of the United States. World stocks of basic metals continued to fall during 1964 as the rising consumption by free world metal-using industries again outpaced world metal output. World trade in nonfuel minerals and related products made overall gains in 1964. Substantial increases were recorded for the trade of iron ores, iron and steel products, nonferrous ores and metals, and chemical and fertilizer minerals and related products. Prices of nonferrous ores and metals rose, while those of iron ore and iron and steel products declined.

DOMESTIC PRODUCTION

Value of Mineral Production.—The value of all U.S. mineral production (metals, nonmetals, and fuels) in current dollars continued the upward surge that started in 1959 and achieved a record high with a 4.4-percent gain over the 1963 figure. The increase in fuels value was relatively small (2 percent) but the increase in metals value was large. Nonfuel minerals value rose 8.9 percent, furnishing 34 percent of total value of mineral production.

The increase in value of metals, 13.1 percent, was due to increases of both production and average prices. Nonmetals increased 7.0 percent in response to the sustained demand from highway and building construction activity and the high demand for chemical and fertilizer minerals.

Value of Mineral Production in 1957–59 Constant Dollars.—The value of mineral production in constant dollars registered another alltime high with a 3.5-percent increase over the 1963 figure; nonfuels increased 6.4 percent and fuels, 2.1 percent. The constant dollar gains were significantly lower than their current dollar equivalents, reflecting increased prices during the year.

Volume of Mineral Production.—The Bureau of Mines index of physical volume of mineral production increased 3.6 percent in 1964 and registered another new high. The metals index rose 7 percent, reflecting a ferrous metals gain of 14 percent and a nonferrous metals increase of 3.6 percent. Nonmetals (except fuels), continuing an upward trend, rose 3.6 percent over the 1963 figure and recorded a new high. Increased production of sand, gravel, stone, and cement made the gain of 5.8 percent in construction materials possible, whereas the gains of phosphate rock, potash, sulfur, sodium compounds including salt, and magnesium minerals were responsible for the 8.7-percent increase in the chemical minerals index. The fuels index rose 2.6 percent in 1964 and was the major factor causing the all-minerals index to reach an alltime high.

The Federal Reserve Board (FRB) mining indexes showed similar upward trends. The FRB index of base mineral manufacturing indicated the following gains in 1964: 14.6 percent for iron and steel; 8.6 percent for nonferrous metals and products; 7.2 percent for clay, glass, and stone products; and 6.2 percent for total industrial production. Industrial production recorded a new high in 1964.

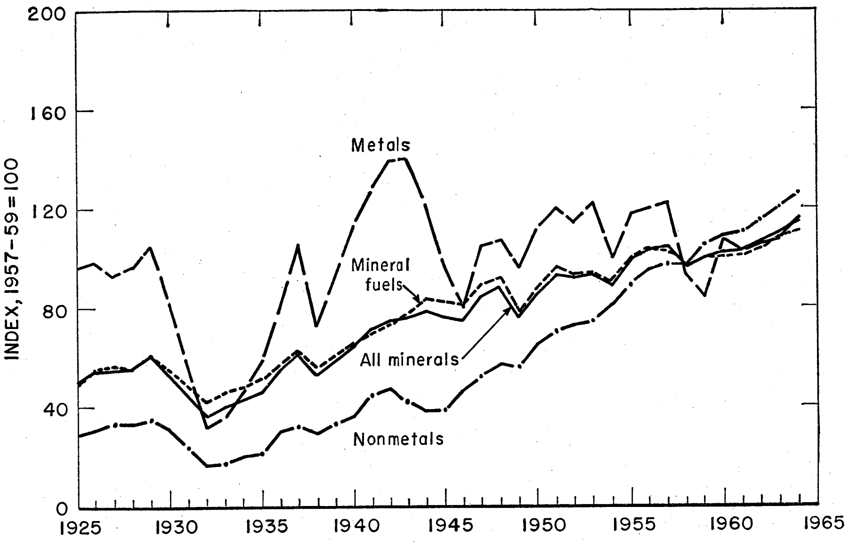

FIGURE 1.—Indexes of physical volume of mineral production in the United States by groups.

TABLE 1.—Value of mineral production in the United States by mineral group[1]

(Millions)

Mineral groups[2]	1960	1961	1962	1963	1964	Change in 1964 from 1963 (percent)
Metals and nonmetals except fuels:						
Nonmetals	$3,868	$3,946	$4,117	$4,318	$4,622	+7.0
Metals	2,022	1,927	1,937	r 2,002	2,265	+13.1
Total	5,890	5,873	6,054	r 6,320	6,887	+9.0
Mineral fuels	12,142	12,357	12,784	r 13,295	13,585	+2.2
Grand total	18,032	18,230	18,838	r 19,615	20,472	+4.4

r Revised.

[1] Includes Alaska and Hawaii.

[2] For details see table 1 in the chapter "Statistical Summary" of the 1964 Minerals Yearbook.

TABLE 2.—Value of mineral production in the United States by mineral group, in 1957–59 constant dollars[1]

(Millions)

Year	Nonmetals (except fuels)	Metals	Nonfuel total	Mineral fuels	Total minerals
1960	$3,841	$1,893	$5,734	$12,228	$17,962
1961	3,930	1,875	5,805	12,296	18,101
1962 r	4,129	1,870	5,999	12,620	18,619
1963 r	4,366	1,873	6,239	13,189	19,428
1964	4,631	2,010	6,641	13,464	20,105

r Revised.

[1] Deflated using the index of implicit unit value.

TABLE 3.—Indexes of the physical volume of mineral production in the United States by groups and subgroups [1]

(1957-59=100)

Year	All minerals	Metals						Nonmetals				Fuels
		Total	Ferrous	Nonferrous				Total	Construction	Chemical	Other	
				Total	Base	Monetary	Other					
1960	102.1	107.5	114.2	103.2	105.5	94.9	[r] 96.6	108.0	108.2	108.5	103.1	100.3
1961	102.9	103.3	94.6	108.8	113.4	93.7	92.1	110.3	110.6	112.0	96.8	101.2
1962	106.0	106.2	92.1	115.1	117.8	95.3	122.0	115.4	117.0	114.0	97.1	104.0
1963	110.8	107.6	95.7	115.1	118.4	[r] 90.3	125.8	121.7	[r] 123.4	[r] 120.1	102.6	108.8
1964	114.8	115.6	108.7	119.3	124.1	91.4	127.3	126.1	130.6	130.6	108.2	111.6

[r] Revised.

[1] For description of index see Bureau of Mines Minerals Yearbook 1956, v. 1, pp. 2-5.

TABLE 4.—Indexes of production of mining, primary metals, clay, glass and stone products, and total industrial production

(1957-59=100)

Year	Mining	Coal, oil, and gas	Metal, stone, and earth minerals	Metal mining	Stone and earth minerals	Primary metals	Iron and steel	Nonferrous metals and products	Clay, glass, and stone products	Total industrial production
1960	101.6	99.7	110.7	111.8	109.8	101.3	100.9	102.8	107.8	108.7
1961	102.6	100.9	110.5	111.9	109.4	98.9	96.5	107.5	106.3	109.8
1962	105.0	103.8	110.9	112.6	109.7	104.6	100.6	119.1	111.1	118.3
1963	107.9	107.0	112.2	112.3	112.1	113.3	109.6	126.7	117.5	124.3
1964 [p]	110.9	109.4	118.1	117.3	118.7	128.2	125.6	137.6	126.0	132.0

[p] Preliminary.

Source: Federal Reserve System, Industrial Production 1957-59 Base, 1962, 172 pp. Federal Reserve System, Federal Reserve Bulletin, February 1964, pp. 224-225; February 1965, pp. 310-311; April 1965, pp. 594-595.

TABLE 5.—Monthly indexes of production, mining, nonfuel mining, metal mining, stone, and earth minerals, seasonally adjusted

(1957-59=100)

Month	Mining[1]			Metal, stone, and earth minerals			Metal mining			Stone and earth minerals		
	1963	1964	Change from 1963 (percent)	1963	1964	Change from 1963 (percent)	1963	1964	Change from 1963 (percent)	1963	1964	Change from 1963 (percent)
January	103.0	108.8	+5.6	111.1	114.7	+3.2	110.1	116.4	+5.7	111.9	113.5	+1.4
February	104.7	108.9	+4.0	109.7	116.4	+6.1	114.3	118.8	+3.9	106.2	114.7	+8.0
March	105.4	108.8	+3.2	112.6	117.0	+3.9	115.7	119.8	+3.5	110.2	115.0	+4.4
April	107.4	109.9	+2.3	113.9	118.5	+4.0	114.5	124.2	+8.5	113.4	114.3	+.8
May	108.5	111.3	+2.6	112.8	117.9	+4.5	116.4	119.4	+2.6	110.1	116.8	+6.1
June	109.4	111.4	+1.8	113.0	119.2	+5.5	112.8	119.2	+5.7	113.2	119.2	+5.3
July	111.3	110.9	(2)	112.1	114.9	+2.5	110.3	107.7	−2.4	113.5	120.2	+5.9
August	111.3	111.9	+.5	111.6	117.7	+5.5	112.8	112.2	−.5	110.7	121.7	+9.9
September	110.3	111.9	+1.5	112.5	116.1	+3.2	113.4	111.3	−1.9	111.9	119.6	+6.9
October	109.1	112.0	+2.7	113.1	118.0	+4.3	109.8	115.7	+5.4	115.5	119.7	+3.6
November	107.5	112.7	+4.8	110.3	125.3	+13.6	106.4	127.1	+19.5	113.2	123.9	+9.5
December	106.6	112.3	+5.3	112.7	122.7	+8.9	111.6	121.8	+9.1	113.5	123.4	+8.7
Annual average	107.9	[p] 110.9	+2.8	112.2	[p] 118.1	+5.3	112.3	[p] 117.3	+4.5	112.1	[p] 118.7	+5.9

[p] Preliminary.
[1] Including fuels.
[2] Less than ½ unit.

Source: Federal Reserve System, Industrial Production Indexes, Federal Reserve Bulletin, February 1964, p. 223; June 1964, p. 769; February 1965, p. 309; April 1965, p. 593.

TABLE 6.—Net supply of principal minerals in the United States and components of gross supply[1]

Commodity	Net supply (Thousand short tons unless otherwise stated)			Components as a percent of gross supply (gross supply=100)						Exports as a percent of gross supply	
				Primary shipments[2]		Secondary production[3]		Imports[4]			
	1963	1964	Change from 1963 (percent)	1963	1964	1963	1964	1963	1964	1963	1964
Ferrous ores, scrap, and metals:											
Iron (equivalent)[5]	[r] 100,970	118,585	+17	48	46	[6] 30	[6] 30	22	24	5	4
Manganese (content)	1,038	997	−4	6	4	----------	----------	[7] 94	[7] 96	1	1
Chromite (Cr_2O_3 content)	[r] 601	643	+7	----------	----------	----------	----------	100	100	1	(8)
Cobalt (content) thousand pounds	[r][9] 10,768	[9] 12,591	+17	W	W	[10] 2	[10] 1	98	99	(8)	(8)
Molybdenum (content) do	39,012	37,705	−3	100	100	----------	----------	(8)	(8)	41	42
Nickel (content)	[r] 139	151	+9	[r] 10	11	[r] 4	4	86	85	(11)	(11)
Tungsten ore and concentrate (W content)–short tons	[r] 4,758	4,119	−13	57	58	----------	----------	[7] 43	42	1	1
Other metallic ores, scrap, and metals:											
Copper (content)	[r] 1,858	1,978	+6	56	54	19	21	[7] 25	[7] 25	14	14
Lead (content)	1,119	1,156	+3	23	25	42	46	[7] 35	[7] 29	(8)	1
Zinc (recoverable content)	1,018	1,034	+2	50	54	6	6	[7] 44	[7] 40	3	3
Aluminum (equivalent)[12]	[r] 2,678	2,809	+5	11	10	4	4	85	86	9	10
Tin (content) long tons	[r] 55,499	47,786	−14	W	W	22	27	78	73	3	5
Antimony (recoverable content)[13] short tons	[r] 39,203	40,191	+3	4	4	[r] 53	54	[r][7] 43	[7] 42	(8)	2
Beryl ore (BeO content) do	710	597	−16	W	W	3	----------	97	100	(8)	(8)
Cadmium (content)[14] do	4,834	5,062	+5	36	34	(15)	(15)	64	66	[r] 12	14
Magnesium (content)	[r] 71,436	73,908	+3	[r][16] 87	[16] 89	[r] 11	9	2	2	[r] 18	18
Mercury 76-pound flasks	[r] 72,322	76,500	+6	26	18	15	30	59	52	(8)	3
Platinum-group metals thousand troy ounces	[r] 1,107	1,188	+7	[r] 4	3	[r][17] 10	[17] 9	[r] 86	88	[r] 5	11
Titanium concentrate:											
Ilmenite and slag (TiO_2 content)	[r] 605	608	+1	78	87	----------	----------	22	13	----------	----------
Rutile (TiO_2 content)	77	112	+45	14	9	----------	----------	86	91	1	2
Uranium concentrate (U_3O_8 content) short tons	23,020	17,144	−26	62	69	----------	----------	38	31	----------	----------

Nonmetals:										
Asbestos	724	840	+16	9	12	----------	91	88	[18] 1	[18] 3
Barite, crude	1,402	1,429	+2	59	58	----------	41	42	----------	----------
Boron minerals and compounds, finished products (gross weight)	361	363	+9	100	100	----------	(8)	(8)	48	49
Bromine and bromine in compounds..million pounds	[r] 191	225	+18	100	100	----------	(8)	(8)	[r] 6	7
Clays	[r] 49,522	52,142	+5	100	100	----------	(8)	(8)	1	2
Fluorspar, finished	832	968	+16	24	22	----------	76	78	(8)	(8)
Gypsum, crude	15,531	16,702	+8	65	63	----------	35	37	(8)	(8)
Mica (except scrap)...thousand pounds	9,349	10,834	+16	1	2	----------	99	98	6	5
Phosphate rock (P_2O_5 content)...thousand long tons	[r] 4,760	5,123	+8	99	99	----------	1	1	[r] 24	26
Potash (K_2O equivalent)	[r] 2,878	3,165	+10	82	80	----------	18	20	13	16
Salt (common)	[r] 31,231	33,369	+7	96	93	----------	4	7	2	2
Sulfur, all forms (content) [19]...thousand long tons	[r] 6,140	6,515	+6	88	88	----------	12	12	21	23
Talc and allied minerals	764	824	+8	97	97	----------	3	3	7	8
Crushed and broken stone	684,876	720,913	+5	100	100	----------	(8)	(8)	(8)	(8)
Sand and gravel	[r] 822,209	871,263	+6	100	100	----------	(8)	(8)	(8)	(8)

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[r] Revised. W Withheld to avoid disclosing individual company confidential data. Figure is not included in net and gross supply.

[1] Net supply is sum of primary shipments, secondary production, and imports, minus exports. Gross supply is total before subtraction of exports.

[2] Primary shipments are mine shipments or mine sales (including consumption by producers) plus byproducts production. Shipments more nearly represent quantities marketed by domestic industry and as such are more comparable to imports. Use of shipment data rather than production data also permits uniform treatment among more commodities.

[3] From old scrap only.

[4] Imports for consumption except where otherwise indicated; scrap is excluded wherever possible in both imports and exports, but all other sources of minerals through refined or roughly comparable stage are included except when commodity description indicates earlier stage. Exports of foreign merchandise (reexports), if any, are included when imports are general.

[5] Iron ore reduced to estimated pig iron equivalent; reported weights used for all other items of supply.

[6] Receipts of purchased scrap.

[7] General imports; corresponding exports are of both domestic and foreign merchandise.

[8] Less than ½ unit.

[9] Sum of secondary production and imports only.

[10] Consumption of purchased scrap.

[11] Mostly manufactured products and scrap; therefore, impossible to determine net content of nickel.

[12] Calculated from the percentage of bauxite mine production (rather than shipments): bauxite imports, and alumina imports used in producing aluminum metal, and converted to aluminum equivalent. Some duplication occurs because of small quantities of loose scrap imported, which is also reflected in secondary production. To avoid a duplicate adjustment for nonmetallic use, exports of bauxite to Canada were excluded from exports.

[13] Based on recovery from all forms as byproducts from domestic and foreign sources.

[14] Primary shipments are calculated as a percentage of total primary production of metal, because part of the domestic primary output is recovered from foreign raw material sources. The quantities recovered from imported raw materials plus imports of cadmium metal are accounted for under imports.

[15] Secondary statistics are included in the primary statistics to avoid disclosing company data.

[16] Primary production of metal.

[17] Recovery from both old and new scrap.

[18] Reexports included.

[19] Includes sulfur content of pyrites production.

NET SUPPLY

Net Supply.—The net supply[3] of most nonfuel minerals and metals increased in 1964. The exceptions follow: Uranium concentrate decreased 26 percent; beryl ore, 16 percent; tin metal, 14 percent; tungsten ore and concentrate, 13 percent; manganese, 4 percent; and molybdenum, 3 percent. The increases were attributable to general improvement of domestic primary and secondary production and imports. Of the 36 commodities included in the net supply tabulation, 30 increased and 6 declined. The apparent increased magnesium exports were a result of expanded coverage.

Source of Supply.—Imports continued to be a vital source of new supply, most noticeably in the metals group. Iron equivalent imports gained substantially in both percentages and volume in 1964, whereas nonferrous base metal imports were mixed. Secondary production maintained and increased slightly its relative position in the net supply of metals.

Source of Imports.—Canada and Mexico continued to be the major sources of mineral imports; South America was the next most important source, followed by Africa, Asia, Oceania, and Europe in order of magnitude. The United States again imported an increased amount of chromite from the U.S.S.R. in 1964.

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[3] Sum of primary shipments, secondary production, and imports, minus exports.

TABLE 7.—Percentage distribution of imports of principal minerals consumed in the United States by area of origin, in 1964 [1]

SITC code	Commodity	Free world						Soviet bloc [2]
		North America	South America	Europe	Asia	Africa	Oceania	
2732100	Gypsum	100	--------	(2)	--------	--------	(2)	--------
2762220 2762240	Graphite, natural	34	--------	24	21	21	--------	(2)
2763000	Salt	94	--------	1	--------	5	--------	--------
2764010 2764020 2764030 2764040 2764050 2764060	Asbestos	83	(2)	1	--------	16	(2)	(2)
2762520 2762540	Magnesia, refractory, caustic-calcined, and crude.	1	--------	90	7	(2)	2	--------
2765210 2765220 2765230 2765240	Mica, including scrap	(2)	29	(2)	66	5	--------	--------
2765420	Fluorspar	81	(2)	19	--------	--------	--------	--------
2768300	Barite, crude	50	23	21	--------	6	--------	--------
2768500	Talc	5	--------	88	7	--------	--------	--------
2810000	Iron ore	65	29	(2)	(2)	6	(2)	--------
2820000	Iron and steel scrap	94	(2)	6	(2)	(2)	(2)	--------
2831100 2833020 2833040	Copper	16	16	--------	68	(2)	--------	--------
5136520 5136540	Bauxite and alumina	70	23	(2)	4	3	--------	--------
2834000	Lead ores and concentrates	31	34	--------	(2)	17	18	--------
2835000	Zinc ores and concentrates	67	28	--------	(2)	4	1	--------
2836000	Tin ores and concentrates	(2)	99	--------	--------	--------	--------	--------
2837020 2837040	Manganese ores and concentrates	6	29	(2)	15	50	--------	--------
2839120	Chrome ores	--------	--------	--------	27	49	--------	24
2839200	Tungsten ores and concentrates	1	63	15	17	1	3	--------
2839310	Tantalum, molybdenum, and vanadium ores and concentrates	(2)	18	7	4	70	1	--------
2839320 2839330	Titanium ores	27	--------	--------	2	--------	71	--------
2839340	Zirconium ores	1	(2)	(2)	--------	7	92	--------
2839810	Antimony ores and needles	19	35	1	1	44	--------	--------
2839820	Beryllium ores and concentrates	1	44	1	(2)	50	4	--------
2839830	Columbium ores and concentrates	40	1	4	2	53	--------	--------
2840200	Copper waste and scrap	48	49	2	1	(2)	--------	--------
2840300	Nickel waste and scrap	47	--------	53	(2)	--------	(2)	--------
2840400	Aluminum waste and scrap	97	--------	3	--------	--------	--------	--------
2840500	Magnesium waste and scrap	68	--------	29	2	1	--------	--------
2840600	Lead waste and scrap	100	--------	(2)	--------	--------	--------	--------
2840700	Zinc waste and scrap	100	--------	--------	--------	--------	--------	--------
2840900	Tin waste and scrap	100	--------	--------	--------	--------	--------	--------
2850000	Platinum group metals, ores, concentrates, and waste	35	1	36	9	2	17	--------
2860000	Uranium and thorium ores and concentrates	--------	--------	--------	32	--------	68	--------
5132500	Mercury, including waste and scrap	5	6	83	6	--------	--------	--------

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[1] U.S.S.R., Bulgaria, East Germany, Albania, Czechoslovakia, Hungary, Poland, Rumania, China, North Korea, North Viet-Nam.

[2] Less than ½ unit.

Source: U.S. Department of Commerce, Bureau of the Census. U.S. Imports of Merchandise for Consumption. FT 125, December 1964.

CONSUMPTION

Patterns.—Domestic consumption of minerals and processed minerals products continued the upward trend of the past few years and generally rose above the 1963 totals; the exceptions were uranium concentrates, primary antimony and bismuth. Ferrous metals and ores made the greatest gains in 1964. Manganese ore consumption increased 22 percent; pig iron, 19 percent; iron ore, 18 percent; steel ingot, 17 percent; molybdenum concentrate, 15 percent; ferrous scrap, 13 percent; and tungsten, 11 percent.

Consumption of nonferrous metals and ores made overall but less spectacular gains in 1964. Platinum metals rose 14 percent; silver, 10 percent; bauxite, 11 percent; zinc metals, 9 percent; copper, 7 percent; aluminum, 6 percent; titanium concentrates and mercury, 6 percent; and refined lead, 3 percent. In 1964 a significant decline of 17 percent in uranium consumption was registered owing to the reduction in the nuclear weapons program. Small declines were recorded in the consumption of antimony and bismuth. Higher construction activities and rising demand for fertilizers required greater quantities of nonmetals. The consumption of asbestos increased 12 percent; lime, 11 percent; phosphate rock and sulfur, 7 percent; salt and sand and gravel, 6 percent; crushed stone and clays, 5 percent; and cement, 4 percent.

Estimated 1975 Consumption.—During 1964–65 the Bureau of Mines revised the projected U.S. consumption of major mineral products for 1975. These new estimates, shown in table 8, were made on the basis of a postwar period trend analysis between commodity consumption and associated economic and related factors such as population, labor force, changing technology, innovation, gross national product, industrial production, construction activity, and farm production. The projected consumption figures for 1975 must not be regarded as predictions and these estimates will change if assumptions about future economic activities change.

Shipments and Orders.—Seasonally adjusted shipments of primary metals continued the upward trend begun in 1961 and achieved a new high in December 1964. Shipments of primary metals in 1964 gained 10 percent over the 1963 total. Net new orders in the primary metals industry continued to surge upward and achieved a new record in 1964, with blast furnace products increasing 22 percent and other primary metals increasing 10 percent. At yearend, unfilled orders of the primary metals industry were 67 percent above the 1963 total, with blast furnace products gaining 103 percent and other primary metals gaining 24 percent.

TABLE 8.—U.S. consumption of major mineral products, 1963, 1964, and projections for 1975

Commodity	1963	1964	Average annual growth rate 1947–64 (percent)	1975 projection	Projected average annual growth rate 1964–75 (percent)
Ferrous:					
Iron ore……thousand long tons	112,535	132,328	+0.6	164,000	+2.0
Pig iron……thousand short tons	72,689	86,382	+1.2	104,800	+1.8
Steel ingot [1]……do	109,000	127,000	+1.2	158.000	+2.0
Ferrous scrap……do	74,621	84,626	+.7	105,300	+2.0
Chromite ores (gross weight):					
Metallurgical grade……do	632	832	+4.0	1,750	+7.0
Refractory grade……do	368	430	+.6	570	+2.6
Chemical grade……do	187	188	+1.7	235	+2.1
Manganese ore (35 percent or more Mn)……do	1,842	2,242	+1.4	3,090	+3.0
Molybdenum (contained Mo)……thousand pounds	49,241	56,409	+5.0	87,800	+4.1
Tungsten (W content)……do	11,061	12,311	+3.3	16,870	+2.9
Nonferrous:					
Aluminum [2]……thousand short tons	[r] 3,040	3,216	+7.3	5,980	+5.8
Bauxite, dry equivalent……thousand long tons	11,318	12,546	+9.8	27,550	+7.4
Antimony, primary……short tons	16,532	15,839	−1.9	27,850	+5.3
Bismuth……thousand pounds	2,175	2,160	[3] +1.5	2,440	+1.1
Copper, primary and old……thousand short tons	1,845	1,967	+.1	2,080	+.5
Lead, primary and secondary……do	1,163	1,202	−.2	1,610	+2.7
Zinc, all classes……do	1,414	1,536	+.9	2,150	+3.1
Mercury……76-pound flasks	77,963	82,608	+3.3	104,000	+2.1
Platinum-group metals……thousand troy ounces	1,003	1,140	+6.9	2,570	+7.7
Silver, industry and the arts……do	110,000	120,500	[4] +.4	155,000	+2.0
Titanium, ilmenite including Ti slag (est. TiO_2 content)……thousand short tons	568,151	602,921	+5.1	1,220,500	+6.6
Uranium (U_3O_8 content)[1]……short tons	14,218	11,847	[5] +8.5	[6] 8,900–14,000	−2.6–+1.6
Nonmetals:					
Asbestos [2]……thousand short tons	[r] 724	813	+.7	870	+.6
Cement [1]……million barrels	361	377	+3.8	660	+5.2
Clays [2]……thousand short tons	[r] 49,522	52,142	+2.1	65,740	+2.1
Lime [7]……do	14,521	16,089	+5.2	27,360	+4.9
Phosphate rock (P_2O_5 content)[2]……do	[r] 15,474	16,546	+4.7	27,200	+4.6
Potash (K_2O content)[2]……do	[r] 2,878	3,165	+6.3	6,250	+6.4
Salt [2]……do	[r] 31,376	33,369	+4.4	53,950	+4.5
Sand and gravel [7]……do	[r] 822	871	[8] +4.3	1,800	+6.8
Stone, crushed……do	686,750	723,300	+8.3	1,500,000	+6.9
Sulfur, all forms [2]……thousand long tons	[r] 6,607	7,084	+2.7	9,700	+2.9

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[r] Revised.

[1] Production.

[2] Apparent consumption.

[3] Growth rate 1951–64.

[4] Growth rate 1947–63.

[5] Growth rate 1956–64.

[6] Faulkner, Rafford, and William McVey. Fuel Resources and Availability for Civilian Nuclear Power for 1964–2000. U.S. Atomic Energy Commission, 1964, table 4. Estimate reflects principally the projected requirements of civilian nuclear powerplants that are based on a plutonium recycle mode of power generating operations; does not include any military requirements or exports of uranium.

[7] Sold or used.

[8] Growth rate 1954–64.

TABLE 9.—Shipments, net new orders, and yearend unfilled orders for selected mineral processing industries

(Millions)

Year and month	Shipments[1]			Net new orders[1]			Unfilled orders at end of period		
	Primary metals	Blast furnaces	All other primary metals[2]	Primary metals	Blast furnaces	All other primary metals[2]	Primary metals	Blast furnaces	All other primary metals[2]
1960	$32,433	$18,285	$14,148	$27,382	$13,763	$13,619	$3,623	$2,033	$1,590
1961	31,659	17,381	14,278	33,107	18,816	14,291	5,129	3,501	1,628
1962	34,016	18,264	15,752	32,619	16,790	15,829	3,761	2,057	1,704
1963	35,325	19,033	16,292	35,508	19,104	16,404	3,930	2,120	1,810
1964:									
January	3,067	1,605	1,462	3,147	1,641	1,506	4,022	2,168	1,854
February	3,034	1,649	1,385	3,074	1,685	1,389	4,169	2,281	1,888
March	3,032	1,615	1,417	3,103	1,675	1,428	4,082	2,203	1,879
April	3,174	1,719	1,455	3,641	2,077	1,564	4,485	2,525	1,960
May	3,154	1,732	1,422	3,175	1,727	1,448	4,513	2,540	1,973
June	3,102	1,563	1,539	3,472	1,943	1,529	4,795	2,748	2,047
July	3,447	1,961	1,486	3,539	2,077	1,462	5,051	3,024	2,027
August	3,216	1,770	1,446	3,280	1,825	1,455	5,049	3,013	2,036
September	3,301	1,786	1,515	3,847	2,296	1,551	5,699	3,608	2,091
October	3,329	1,843	1,486	3,767	2,203	1,564	6,104	3,956	2,148
November	3,434	1,933	1,501	3,663	2,072	1,591	6,370	4,125	2,245
December	3,656	2,074	1,582	3,821	2,243	1,578	6,559	4,311	2,248
Total	38,832	21,236	17,596	41,304	23,304	18,000	6,559	4,311	2,248

[1] Monthly figures are seasonally adjusted and do not add to totals.

[2] All other primary metals can be obtained by subtracting blast furnaces from primary metals.

Sources: U.S. Department of Commerce, Bureau of the Census. Manufacturers' Shipments, Inventories and Orders: 1947–1963. Revised. Series M 3-1, October 1963, pp. 31–37, 44–48. U.S. Department of Commerce, Office of Business Economics. Survey of Current Business. V. 45, No. 3, March 1965, pp. S–5, S–6.

STOCKS

Indexes of Stocks.[4]—Bureau of Mines index of physical stocks held by mineral manufacturers, consumers, and dealers at yearend was 7 percent lower than in 1963; stocks have shown a continuous decline since 1960. Iron ore stocks dropped 7 percent from the 1963 figure. Manganese and ferromanganese ores and chromite stocks decreased, accounting for the 15-percent decline of the other ferrous index. The reduction of lead and copper stocks accounted for the major portion of the 9-percent decline of the base nonferrous stock index, whereas the depletion of tin stocks was principally responsible for the 3-percent drop of the other nonferrous index.

The index of stocks held by primary producers at yearend declined 8 percent in 1964. Of the major group indexes, the index of metal stocks showed the largest decrease, 11 percent. Iron ore stocks dropped 9 percent from the 1963 figure. The 83-percent depletion of tungsten stocks wiped out the rise in molybdenum stocks and resulted in a 36-percent decline of the other ferrous stocks index. Nonferrous stocks decreased 3 percent in 1964. An 8-percent depletion of sulfur stocks was principally responsible for the 6-percent drop of the nonmetals index.

Value of Inventories.—The value of seasonally adjusted inventories held by firms in the primary iron and steel industry in December was 5 percent higher than that of December 1963; in other primary metal industries the value rose 1 percent. Aggregate primary metal industry inventories increased slightly over 3 percent above those of 1963. Stone, clay and glass products manufacturing inventories rose 3 percent in 1964.

TABLE 10.—Index of stocks of mineral manufacturers, consumers, and dealers at yearend

(1957-59=100)

Yearend	Total metals and nonmetals[1]	Metals					Nonmetals
		Total	Iron	Other ferrous	Base nonferrous	Other nonferrous	
1960	110	110	107	108	108	127	118
1961	103	102	99	98	98	126	120
1962	100	99	98	90	101	104	[r] 128
1963	95	93	91	85	97	98	[r] 129
1964	88	86	85	72	88	95	128

[r] Revised.
[1] Excludes fuels.

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[4] See Wang, Kung-Lee and Edward E. Johnson, Review of the Mineral Industries (Metals and Nonmetals Except Fuels): BuMines Minerals Yearbook 1963, v. 1, 1964, p. 20.

TABLE 11.—Index of stocks of crude minerals at mines or in hands of primary producers at yearend

(1957-59=100)

Yearend	Metals and nonmetals	Metals				Nonmetals
		Total	Iron ore	Other ferrous	Nonferrous	
1960	110	154	175	64	161	90
1961	121	134	146	63	169	115
1962	124	147	164	73	149	113
1963	[r] 123	[r] 143	[r] 160	69	[r] 154	[r] 113
1964	113	127	145	44	149	106

[r] Revised.

TABLE 12.—Seasonally adjusted book value of product inventory for selected mineral processing industries

(Millions)

Year and month	Stone, clay, and glass products	Primary metals		
		Blast furnaces, steelworks	Other primary metals	Total
1960: December	$1, 458	$3, 389	$2, 273	$5, 662
1961: December	1, 468	3, 691	2, 286	5, 977
1962: December	1, 492	3, 528	2, 345	5, 873
1963: December	1, 544	3, 533	2, 385	5, 918
1964:				
December	1, 587	3, 707	2, 404	6, 111
January	1, 539	3, 534	2, 389	5, 923
February	1, 535	3, 526	2, 403	5, 929
March	1, 536	3, 561	2, 411	5, 972
April	1, 551	3, 547	2, 407	5, 954
May	1, 579	3, 594	2, 420	6, 014
June	1, 595	3, 628	2, 391	6, 019
July	1, 574	3, 609	2, 392	6, 001
August	1, 586	3, 670	2, 386	6, 056
September	1, 572	3, 688	2, 375	6, 063
October	1, 595	3, 714	2, 382	6, 096
November	1, 593	3, 776	2, 377	6, 153

Sources: U.S. Department of Commerce, Bureau of the Census. Manufacturers' Shipments, Inventories, and Orders: 1947–1963. Revised, Series M 3–1, October 1963, pp. 62–67. U.S. Department of Commerce, Office of Business Economics. Survey of Current Business. V. 45, No. 3, March 1965, p. S–5.

LABOR AND PRODUCTIVITY

Employment.—Total employment in the nonfuel mining industries increased in 1964, thus halting the downward trend apparent since 1960.

The following tabulation shows percentage changes in average total employment compared with 1963 data:

	Percent
All industries	+2. 7
Mining (including fuels)	No change
Metals and nonfuel minerals	+1. 8
Metal mining	+1. 6
Nonmetal mining and quarrying	+1. 9
Coal mining	−2. 5
Crude petroleum and natural gas	−. 2
Minerals manufacturing [1]	+5. 4

[1] Based upon categories listed under mineral manufacturing in table 13.

While employment in iron mining rose 9 percent over that of 1963, employment in copper, lead, zinc and uranium mining continued to decline. Employment in the mineral manufacturing industries was generally higher; with employment at blast furnaces, steelworks and rolling mills showing the largest increase.

Employment in all mining industries in 1964 continued to lag behind that of all industries. The gains made by nonfuel mining industries were offset principally by declines in coal mining. Mineral manufacturing reversed the downward trend started in 1961 and surpassed the percentage increase attained by all industries in 1964.

Hours and Earnings.—Average weekly hours of production workers in the (nonfuel) mining industry rose slightly in 1964. Hourly and weekly earnings increased 3.0 and 3.8 percent, respectively. Weekly hours of metal mining rose 1 percent in 1964; iron ore mining gained 2.8 percent, which compensated for the loss in nonferrous mining. Both hourly and weekly earnings in metal mining increased. Quarrying and nonmetallic mining followed a similar trend. The weekly hours worked in mineral manufacturing remained fairly stable, except for a 3-percent increase registered by the blast furnaces, steelworks, and rolling mills industry. Both hourly and weekly earnings of mineral manufacturing registered some overall gains.

Labor Turnover Rates.—Accession rates for all metal mining rose slightly. The gain in other metal mining offset the decline in iron ore and copper ore mining. Separation rates in all metal mining declined slightly as increased rates in copper mining did not compensate for a steep drop in iron ore mining. The layoff rates in all metal mining declined one-third from the 1963 figures. Accession, separation, and layoff rates for the mineral manufacturing industries in 1964 generally declined, whereas those for all manufacturing were mixed. The accession rate for all manufacturing rose slightly, the separation rate was the same, and the layoff rate declined.

Wages and Salaries.—Wages and salaries in the mining industry, including fuels, continued the upward trend begun in 1961. However the 3-percent increase in 1964 was below the 6- and 5-percent gains reported for all industries and manufacturing, respectively. The average annual earnings of full-time employees in mining rose 3 percent and remained slightly higher than earnings in all industries and manufacturing.

Productivity.[5]—Productivity per worker in copper ore mining gained substantially over that of 1963, and iron ore mining productivity rose slightly, resulting in an overall increase of metal mining productivity. The productivity trend in recoverable copper and iron metal followed the same pattern. The productivity in recoverable copper in 1964 was less than that of copper ore mining, while the productivity in recoverable iron content was greater than that of iron ore. This indicated that the average grade of iron ore mined in 1964 was slightly improved, whereas the average grade of copper ore mined was a trifle lower than in 1963.

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[5] Review is based on preliminary estimates.

TABLE 13.—Total employment in the mineral industries (nonfuel) in the continental United States by industry

(Thousands)

Year	Mining				
	Total	Nonmetal mining and quarrying	Metal		
			Total [1]	Iron	Copper
1960	216.8	123.0	93.8	33.2	28.3
1961	207.2	119.8	87.4	26.9	29.0
1962	[r]200.4	[r]118.1	[r]82.3	[r]25.2	28.5
1963 [r]	198.2	117.7	80.5	24.7	27.7
1964	201.8	120.0	81.8	26.9	27.0

Year	Mineral manufacturing			
	Fertilizers	Cement, hydraulic	Blast furnaces steel works, and rolling mills	Primary metals, nonferrous smelting and refining
1960	35.5	42.8	577.1	70.3
1961	35.8	40.2	526.5	66.6
1962	[r]36.8	[r]39.8	522.3	68.1
1963	[r]38.6	[r]38.9	[r]519.7	68.8
1964	39.2	38.7	553.5	70.3

[r] Revised.

[1] Includes other metal mining not shown separately.

Source: U.S. Department of Labor, Bureau of Labor Statistics. Employment and Earnings. V. 11, No. 6, December 1964, to v. 11, No. 9, March 1965, table B-2. U.S. Department of Labor, Bureau of Labor Statistics. Employment and Earnings Statistics for the United States 1909–1964. Bull. 1312-2, December 1964.

TABLE 14.—Average hours and gross earnings of production and related workers in the mineral industries (nonfuel) in continental United States by industries

Year	Weekly Earnings	Weekly Hours	Hourly earnings	Weekly Earnings	Weekly Hours	Hourly earnings	Weekly Earnings	Weekly Hours	Hourly earnings
	Total[1]			Metal mining					
				Total[2]			Iron ores		
1960	$102.86	42.9	$2.40	$111.19	41.8	$2.66	$114.73	39.7	$2.89
1961	105.68	42.9	2.57	113.44	41.4	2.74	115.50	38.5	3.00
1962	[r]110.33	43.2	2.56	117.45	41.5	2.83	122.19	39.8	3.07
1963	[r]112.95	43.2	2.63	118.66	41.2	2.88	[r]120.04	[r]39.1	3.07
1964	117.27	43.4	2.71	122.72	41.6	2.95	125.83	40.2	3.13
	Metal mining—Continued			Quarrying and nonmetallic mining			Mineral manufacturing		
	Copper ores						Fertilizers, complete and mixing only		
1960	$116.77	44.4	$2.63	$96.58	43.7	$2.21	$79.55	43.0	$1.85
1961	119.03	43.6	2.73	100.09	43.9	2.28	80.94	42.6	1.90
1962	120.70	42.8	2.82	105.43	44.3	2.38	84.12	42.7	1.97
1963	124.56	43.1	2.89	109.03	44.5	2.45	90.23	43.8	2.06
1964	130.42	42.9	3.04	113.54	44.7	2.54	92.88	43.4	2.14
	Mineral manufacturing—Continued								
	Cement, hydraulic			Blast furnaces, steel and rolling mills			Nonferrous smelting and refining		
1960	$102.87	40.5	$2.54	$117.04	38.0	$3.08	$108.09	41.1	$2.63
1961	106.52	40.5	2.63	123.84	38.7	3.20	110.16	40.8	2.70
1962	112.75	41.0	2.75	128.31	39.0	3.29	114.95	41.2	2.79
1963	116.60	41.2	2.83	134.40	40.0	3.36	[r]118.14	41.6	[r]2.84
1964	121.30	41.4	2.93	140.15	41.1	3.41	120.64	41.6	2.90

[r] Revised.

[1] Weighted average of data computed, using figures for production workers as weights.

[2] Includes other metal mining not shown separately.

Source: U.S. Department of Labor, Bureau of Labor Statistics. Employment and Earnings. V. 11, No. 9, March 1965, table C-2. U.S. Department of Labor, Bureau of Labor Statistics. Employment and Earnings Statistics for the United States 1909-64. Bull. 1312-2, December 1964.

TABLE 15.—Labor-turnover rates in the mineral industries [1]

(Per 100 employees)

Turnover rate	All manufacturing	Hydraulic cement products	Blast furnaces, steel and rolling mills	Nonferrous smelting and refining	Metal mining	Iron ores	Copper ores
Total accession rate:							
1963	3.9	3.3	3.2	2.4	3.1	3.4	2.2
1964	4.0	2.9	2.9	2.3	3.2	2.7	2.7
Total separation rate:							
1963	3.9	3.5	2.8	2.1	3.1	2.7	2.1
1964	3.9	3.0	1.8	2.1	3.0	2.3	2.5
Layoff rate:							
1963	1.8	2.4	1.7	.8	1.1	1.8	.5
1964	1.7	2.0	.5	.6	.7	1.3	.3

[1] Monthly rates are available in Employment and Earnings as indicated in source.

Source: U.S. Department of Labor, Bureau of Labor Statistics. Employment and Earnings. V. 11, No. 6, December 1964, to v. 11, No. 9, March 1965, table D-2. U.S. Department of Labor, Bureau of Labor Statistics. Employment and Earnings Statistics for the United States 1909-64. Bull. 1312-2, December 1964.

TABLE 16.—Wages, salaries, and average annual earnings in the United States

	Millions of dollars		Percent change	
	1963	1964	1962-63	1963-64
Wages and salaries:				
All industries, total	312,148	331,554	+5.1	+6.2
Mining	3,798	3,916	+.9	+3.1
Manufacturing	98,042	102,999	+4.1	+5.1
	Dollars		Percent change	
Average earnings per full-time employee:				
All industries, total	5,190	5,393	+3.6	+3.9
Mining	6,267	6,451	+3.9	+2.9
Manufacturing	5,911	6,104	+3.4	+3.3

Source: U.S. Department of Commerce, Office of Business Economics, Survey of Current Business. February 1965, table 17.

TABLE 17.—Labor-productivity indexes for copper- and iron-ore mining

(1957-59=100)

Year	Copper, crude ore mined per—		Iron, crude ore mined per—	
	Production worker	Man-hour	Production worker	Man-hour
1954-58 (average)	90.7	88.0	96.7	94.8
1959	110.0	105.8	100.9	101.6
1960	116.9	108.2	122.7	116.3
1961	[r] 117.4	[r] 110.6	[r] 138.4	[r] 135.2
1962	125.8	120.7	[r] 154.6	[r] 146.1
1963	126.2	120.3	164.9	158.7
	Copper metal recovered [1] per—		Iron metal recovered [1] per—	
	Production worker	Man-hour	Production worker	Man-hour
1954-58 (average)	94.1	91.3	105.0	102.7
1959	105.3	101.3	93.9	94.6
1960	112.9	104.5	112.0	106.2
1961	[r] 115.6	[r] 109.0	[r] 115.1	[r] 112.4
1962	124.1	119.1	[r] 123.6	[r] 116.9
1963	126.0	120.1	126.3	121.5

[r] Revised.

[1] Figures refer to usable rather than recoverable metal. For iron usable ore is that product with the desired iron content (by selective mining, mixing of ores, washing, jigging, concentrating, sintering).

Source: U.S. Department of Labor, Bureau of Labor Statistics. Index of Output per Man-Hour, Selected Industries. September 1964, pp. 12-15.

PRICES AND COSTS

Index of Mine Value.—The average unit mine value of all minerals (including fuels) rose slightly, due almost entirely to an 11.3-percent increase of metal ores. In the metals subgroup, the ferrous metals ores rose 3.7 percent in 1964, whereas the nonferrous metals ores gained significantly with an increase of 8.7 percent over the 1963 value. Copper, lead, mercury, and zinc were responsible for the gains made in the nonferrous subgroup. In the nonmetals subgroup, the 1-percent gain made in the aggregate nonmetals index was totally attributed to increased prices for certain chemical nonmetals, principally salt and bromine.

Index of Implicit Unit Value.—The index of implicit unit value reflected the unit price change implied in the Bureau of Mines index of physical volume of mineral production and its value series of total mineral production. Implicit unit value of all minerals increased 1 percent in 1964. The 5 percent increase in the metals index accounted for the bulk of the rise in the overall index. Aluminum, copper, lead, and zinc were principally responsible for the increases.

Prices.—Most processed mineral commodity prices rose gradually, but ferrous and nonferrous scrap and base nonferrous metals rose sharply. Prices of nonferrous metals gained 7 percent; pig lead, zinc slab, and copper ingot rose 22 percent, 12 percent, and 4 percent, respectively. Ferrous scrap increased 19 percent, whereas nonferrous scrap gained 17 percent. Nonmetals prices were generally steady.

Costs.—Prices of cost items shown in table 22 were mixed. Coke, construction machinery and equipment, and lumber prices rose moderately, whereas coal, gas fuels, industrial chemicals, and explosives prices made little or no change. Prices of petroleum refined products decreased 5 percent in 1964.

In general, prices of machinery and equipment used in mining rose over 2 percent in 1964. The percentage changes from 1963 figures for major items follow:

	Percent change from 1963
Mining machinery and equipment	+1.6
Power cranes, draglines, shovels, etc	+2.8
Tractors, other than farm	+3.5
Construction machinery and equipment	+2.6

Relative Labor Cost.—The 1964 index of labor cost for metal mining declined slightly for both copper and iron ore. The values of recoverable copper and iron per man-hour gained 12 and 2 percent, respectively, over the 1963 figures, and both recorded new highs. The labor cost per dollar of recoverable copper declined 5 percent, whereas that of recoverable ferrous metals was unchanged.

Index of Principal Metal Mining Expenses.[6]—This index excludes capital costs and contract work expenses; consequently, it does not represent changes in total unit cost of metal mining. It does, however, gage the impact of labor cost, production changes, productivity, and fluctuation in prices of current supplies, fuels, and electric energy used by the mining industry. The total index due to lower prices of labor, fuels and electric energy continued the gradual decline that commenced in 1959.

TABLE 18.—Index of average unit mine value of minerals produced in the United States by group and subgroup

(1957-59=100)

Year	All minerals	Metals						Nonmetals				Fuels
		Total	Ferrous	Nonferrous				Total	Construction	Chemical	Other	
				Total	Base	Monetary	Other					
1960	98	105	102	107	109	102	99	102	104	100	101	97
1961	98	103	105	99	98	104	100	102	103	101	101	97
1962	98	102	104	101	99	111	99	102	103	99	102	97
1963	98	106	108	[r] 103	100	118	103	102	104	97	[r] 105	96
1964	99	118	112	112	110	119	112	103	104	98	105	95

[r] Revised.

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[6] This index is for iron ore and copper mining only.

TABLE 19.—Index of implicit unit value of minerals produced in the United States

(1957-59=100)

Year	All minerals	Metals						Nonmetals				Fuels
		Total	Ferrous	Nonferrous				Total	Construction	Chemical	Other	
				Total	Base	Monetary	Other					
1960	100.9	106.8	101.8	110.1	111.7	99.7	98.6	100.7	100.7	99.5	102.9	99.3
1961	101.1	102.8	103.9	103.7	103.4	101.2	[r]97.6	100.4	99.8	101.7	106.5	100.5
1962	[r]101.6	[r]103.6	103.5	106.8	[r]106.2	[r]108.2	[r]99.7	[r]99.7	[r]99.2	100.4	110.1	[r]101.3
1963	[r]101.4	[r]106.9	107.7	[r]106.4	[r]106.5	[r]118.2	[r]109.5	[r]98.9	[r]98.0	[r]99.1	[r]114.6	[r]100.8
1964 [p]	102.4	112.7	110.4	116.3	114.6	117.4	119.3	99.8	98.7	99.9	119.9	100.9

[p] Preliminary.
[r] Revised.

TABLE 20.—Price indexes for selected metals and mineral commodities

(1957-59=100)

Commodity	Annual average		Percent change from 1963
	1963	1964	
Metals and metal products	100.1	102.8	+2.7
Iron and steel	99.1	100.5	+1.4
Iron ore	93.1	90.6	−2.7
Iron and steel scrap	66.5	79.3	+19.2
Semifinished steel products	102.3	103.5	+1.2
Finished steel products	102.0	102.8	+.8
Foundry and forge shop products	103.6	104.7	+1.1
Pig iron and ferroalloys	[r]81.8	77.6	−5.1
Nonferrous metals	99.1	105.9	+6.9
Primary metal refinery shapes	102.1	111.2	+8.9
Aluminum ingot	90.2	94.6	+4.9
Copper, ingot, electrolytic	106.1	110.6	+4.2
Lead, pig, common	85.8	104.6	+21.9
Zinc, slab, prime western	108.5	121.7	+12.2
Nonferrous scrap	100.1	117.3	+17.2
Nonmetallic mineral products	101.3	101.5	+.2
Concrete ingredients	103.0	102.8	−.2
Sand, gravel, and crushed stone	104.8	104.8	------------
Concrete products	101.7	100.9	−.8
Structural clay products	103.6	104.4	+.8
Gypsum products	105.4	108.2	+2.7
Other nonmetallic minerals	101.4	101.5	+ 1
Building lime	110.1	110.3	+.2
Insulating materals	90.7	90.9	+.2
Asbestos cement shingles	110.8	111.0	+.2
Bituminous binders (1958=100)	100.0	100.0	------------
Fuels and related products and power	99.8	97.1	−2.7
Fertilizer materials	99.9	100.1	+.2
Nitrogenates	94.3	94.1	−.2
Phosphates	108.2	110.4	+2.0
Phosphate rock	123.4	128.9	+4.5
Potash	116.0	113.9	−1.8
Muriate, domestic	113.5	111.1	−2.1
Sulfate	117.5	117.3	−.2
All commodities other than farm and food	100.7	101.2	+.5
All commodities	100.3	100.5	+.2

[r] Revised.

Source: U.S. Department of Labor, Bureau of Labor Statistics. Wholesale Prices and Price Indexes. February 1964 and January 1965.

TABLE 21.—Price indexes for mining construction and material handling machinery and equipment

(1957-59=100)

Year	Construction machinery and equipment	Mining machinery and equipment	Oilfield machinery and tools	Power cranes, draglines, shovels, etc.	Specialized construction machinery	Portable air compressors	Scrapers and graders	Contractors air tools, handheld	Mixers, pavers, spreaders, etc.	Tractors, other than farm
1960	105.8	106.4	100.3	105.1	106.9	105.4	104.7	108.2	106.7	106.4
1961	107.5	107.8	101.8	105.4	107.8	114.1	104.4	113.5	108.4	108.0
1962	107.8	108.4	103.2	106.1	107.4	113.7	105.3	113.5	110.3	108.5
1963	109.6	109.1	102.6	108.8	108.1	115.1	108.5	113.5	112.1	110.8
1964	112.4	110.8	104.1	111.8	108.5	117.6	110.8	(1)	116.3	114.7

[1] Series discontinued in 1964.

Source: U.S. Department of Labor, Bureau of Labor Statistics. Wholesale Prices and Price Indexes, February 1964 and January 1965.

TABLE 22.—Price indexes for selected cost items in nonfuel mineral production

(1957-59=100, unless otherwise specified)

Commodity	1964		Change from January (percent)	Annual average		Change from 1963 (percent)
	January	December		1963	1964	
Coal	98.3	98.2	−0.1	96.9	96.9	----------
Coke	103.6	107.3	+3.6	103.6	106.3	+2.6
Gas fuels (January 1958=100)	124.8	124.0	−.6	122.8	122.8	----------
Petroleum and refined products	96.6	94.0	−2.7	97.2	92.7	−4.6
Industrial chemicals	94.3	94.2	−.1	94.8	94.2	−.6
Lumber	99.2	99.1	−.1	98.9	100.7	+1.8
Explosives	112.0	111.4	−.5	[r] 112.3	111.8	−.4
Construction machinery and equipment	111.8	113.7	+1.7	109.6	112.4	+2.6

[r] Revised.

Source: U.S. Department of Labor, Bureau of Labor Statistics. Monthly Labor Review. V. 88, No. 3, March 1965, pp. 368–369; No. 4, April 1965, pp. 490–491.

TABLE 23.—Indexes of relative labor costs, copper and iron ore mining[1]

(1957-59=100)

Year	Labor costs per pound of recoverable metal		Value of recoverable metal per man-hour		Labor costs per dollar of recoverable metal	
	Copper	Iron ore	Copper	Iron ore	Copper	Iron ore
1960	105	99	116	107	95	98
1961 [r]	105	97	113	14	101	96
1962	98	[r] 96	126	[r] 112	93	[r] 100
1963	100	[r] 92	127	[r] 115	94	[r] 97
1964	99	91	142	117	89	97

[r] Revised.

[1] Computed from data found in U.S. Department of Labor, Employment and Earnings and Wholesale Price Indexes.

TABLE 24.—Indexes of principal metal mining expenses [1]

(1957-59=100)

Year	Total	Labor	Supplies	Fuels	Electric energy
1960	102	101	102	100	102
1961	101	100	101	101	103
1962	[r] 99	[r] 96	101	100	[r] 103
1963	[r] 98	[r] 95	102	100	[r] 102
1964	97	94	102	97	101

[r] Revised.

[1] Indexes constructed using the following weights derived from the 1958 Census of Mineral Industries: Labor, 59.37; explosives, 2.42; steel mill shapes and forms, 3.51; all other supplies, 25.24; fuels, 5.08; electric energy, 4.38; and data from U.S. Department of Labor, Bureau of Labor Statistics, Wholesale Price Index. The index is computed for iron and copper ores only because sufficient data is not available for other mining sectors.

INCOME

National Income Originated.—Income originating in the mining industry increased 4 percent in 1964 and reversed the downward trend started in 1961. However, it still lagged behind the increase of all industries and manufacturing incomes which recorded 7 and 8 percent gains, respectively. Consequently, the relative share of income originating from mining activities in the United States declined slightly.

Profits and Dividends.—The annual profit rate on stockholders' equity (after corporate income taxes) made notable gains in 1964. The primary iron and steel industry continued its upward trend and achieved another substantial gain with a 26-percent increase in annual profit rate over the 1963 figure. The primary nonferrous metals industry also registered a spectacular gain with a rise of 29 percent. The overall primary metals industry rate was 28 percent greater than in 1963 and more than double the growth rate of all manufacturing. The profit rate of stone, clays, and glass products and chemical and allied products industries gained but lagged slightly behind that of all manufacturing. Dividends paid by the minerals processing industry increased, but the rate of increase was still less than that for all manufacturing.

TABLE 25.—National income originated in the mineral industries in the United States

Industry	Income, million dollars			Change from 1963 (percent)
	1962	1963	1964	
Mining	5,653	5,971	6,233	+4.4
Metal mining	758	807	882	+9.3
Coal mining	1,141	1,211	1,274	+5.2
Crude petroleum and natural gas	2,811	2,928	2,981	+1.8
Mining and quarrying of nonmetallic minerals	943	1,025	1,096	+6.9
Manufacturing	136,988	143,817	154,662	+7.5
Chemicals and allied products	9,910	10,486	11,291	+7.7
Petroleum refining and related industries	4,489	4,805	4,814	+0.2
Stone, clay, and glass products	4,748	5,048	5,394	+6.9
Primary metal industries	10,937	11,440	12,655	+10.6
All industries, total	457,687	481,110	514,389	6.9

Source: U.S. Department of Commerce, Office of Business Economics, Survey of Current Business. V. 45, No. 8, August 1965.

Business Failures.—The number of failures in mining companies including fuels was the lowest since 1957 although current liabilities of mining failures increased $12 million over the 1963 figure.

TABLE 26.—Annual average profit rates on shareholders equity, after taxes and total dividends, mineral manufacturing corporations

Industry	Annual profit rate (percent)			Total dividends (millions)		
	1963	1964	Change from 1963 (percent)	1963	1964	Change from 1963 (percent)
All manufacturing [1]	10.3	11.6	+12.6	$9,868	$10,810	+9.6
Primary metals	[r] 7.2	9.2	+27.8	840	913	+8.7
Primary iron and steel [2]	7.0	8.8	+25.7	514	546	+6.2
Primary nonferrous metals [2]	7.6	9.8	+28.9	[r] 325	367	+12.9
Stone, clays, and glass products	8.7	9.6	+10.3	313	326	+4.2
Chemical and allied products	12.9	14.4	+11.6	1,446	1,486	+2.8

[r] Revised.
[1] Except newspapers.
[2] Included in primary metals.

Source: Federal Trade Commission, Securities and Exchange Commission. Quarterly Financial Report for Manufacturing Corporations. First Quarter 1964 and 4th Quarter 1964, tables 4 and 8.

TABLE 27.—Industrial and commercial failures and liabilities

Industry	1962	1963	1964
Mining: [1]			
Number of failures	85	84	70
Current liabilities thousand dollars	48,278	18,269	30,030
Manufacturing:			
Number of failures	2,490	2,325	2,184
Current liabilities thousand dollars	351,723	[r] 539,430	331,834
All industrial and commercial industries:			
Number of failures	15,782	14,374	13,501
Current liabilities thousand dollars	1,213,601	1,352,593	1,329,223

[r] Revised.
[1] Including fuels.

Source: Dun & Bradstreet, Inc., Business Economics Department, Business Conditions Staff. Monthly Business Failures. New York, N.Y., January 1964, p. 2; January 1965, p. 2.

INVESTMENT [7]

New Plant and Equipment.—In 1964 expenditures for new plant and equipment by firms in the mining industry increased $150 million, or 14.4 percent, over the 1963 figures. Investment by mining firms lagged behind the upward trend set by all manufacturing industries.

Compared with an 18-percent gain in capital expenditure for all manufacturing, the following industries recorded increases in 1964: Primary iron and steel, 36 percent; petroleum, 15 percent; and chemical, 22 percent. Primary nonferrous metals industries and stone, clay and glass products manufacturing lagged behind all manufacturing with increases of 17 and 11 percent, respectively.

Issues of Mining Securities.—The mining industry (including fuels) supplied 3 percent of all new corporation securities offered in 1964. This was the highest since 1958 and reversed the downward trend of preceding years. The percentage distribution between types of securities in mining followed the established pattern of principally bond and common stock finance. Total gross proceeds in new mining securities increased $207 million in 1964 and were 97 percent greater than 1963 gross proceeds; this compared with a 14-percent gain in total corporate and a 14-percent drop in all manufacturing.

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[7] U.S. Securities and Exchange Commission ceased publication of the Indexes of Common Stock Prices as of 1964.

The proposed uses of estimated net proceeds from mining corporate offerings in 1964 follow: Plant and equipment, 41 percent; working capital, 27 percent; retirement of securities, 2 percent; and other purposes, 30 percent.[8]

Foreign Investment.[9]—The value of U.S. direct private foreign investment in mining and smelting increased $167 million during 1963; 1964 data are not available. Gains were made in Canada, Africa, and Australia of $58 million, $44 million, and $28 million, respectively, while Latin America suffered a net disinvestment of $6 million. Net capital outflow from the United States accounted for only 39 percent of the 1963 increase of direct foreign investment, compared with 75 percent in 1962 and 53 percent in 1961. The undistributed earnings of subsidiaries accounted for another 40 percent of the 1963 increase, compared with 32 percent in 1962. The 1963 net earnings of subsidiaries and branches of U.S. mining and smelting firms decreased $8 million from the 1962 total and income also decreased $21 million. In 1963, direct private investment of U.S. foreign mining and smelting industries again lagged behind all industries in all categories—value, net capital flow, earnings, and income.

The 1963 foreign plant and equipment expenditure of U.S. mining and smelting firms was $398 million, 9 percent less than the revised 1962 expenditure of $438 million. Canada suffered a loss of $50 million in 1963 and more than accounted for all the 1963 decline.

To finance foreign capital expenditure and working capital, U.S. mining and smelting companies affiliated abroad relied principally on internally generated funds—net income and depreciation and depletion charges. Of the total $875 million source of investment fund in 1963, $732 million came from foreign affiliates' own resources—cash flow from depreciation and depletion ($239 million) and from net income ($493 million). Funds from the United States accounted for only $41 million, 5 percent of the total sources in 1963. The internally generated fund of the U.S. mining and smelting foreign affiliates accounted for 84 percent of total fund needs in 1963, compared with 84 percent for petroleum extraction industries and 79 percent for manufacturing industries.

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[8] U.S. Securities and Exchange Commission. Statistical Bulletin. V. 24, No. 6, June 1965, p. 15.

[9] U.S. Department of Commerce, Office of Business Economics. Survey of Current Business. V. 44, No. 8, August 1964, pp. 8-14.

TABLE 28.—Expenditures on new plant and equipment by firms in mining and selected mineral manufacturing industries

(Billions)

Industry	1962	1963	1964
Mining [1]	$1.08	$1.04	$1.19
Manufacturing	14.68	15.69	18.58
Primary iron and steel	1.10	1.24	1.69
Primary nonferrous metals	.31	.41	.48
Stone, clay, and glass products	.58	.61	.68
Chemicals	1.56	1.61	1.97
Petroleum	2.88	2.92	3.36

[1] Including fuels.

Source: U.S. Department of Commerce, Office of Business Economics. Survey of Current Business. V. 44, No. 3, March 1964, p. 13; v. 45, No. 3, March 1965, p. 8.

TABLE 29.—Estimated gross proceeds of new corporate securities offered for cash in the United States in 1964 [1]

Type of security	Total corporate		Manufacturing		Extractive [2]	
	Millions	Percent	Millions	Percent	Millions	Percent
Bonds	$10,866	77.9	$2,818	92.5	$289	68.6
Preferred stock	412	3.0	42	1.4	5	1.2
Common stock	2,679	19.1	186	6.1	127	30.2
Total	13,957	100.0	3,046	100.0	421	100.0

[1] Substantially all new issues of securities offered for cash sale in the United States in amounts over $100,000 and with terms to maturity of more than 1 year are covered in these data.

[2] Including fuels.

Source: U.S. Securities and Exchange Commission. Statistical Bulletin. V.24, No. 4, April 1965, p. 10.

TABLE 30.—Direct private investments of the United States in foreign mining and smelting industries in 1963

(Millions)

Country and areas	Mining and smelting					All industries				
	Value	Net capital outflow	Undistributed earnings of subsidiaries	Earnings [1]	Income [2]	Value	Net capital outflow	Undistributed earnings of subsidiaries	Earnings [1]	Income [2]
Canada	$1,540	$1	$45	$94	$53	$13,016	$339	$528	$930	$441
Latin America, total	1,093	−6	5	147	141	8,657	64	173	964	801
Mexico	116	−4	−1	11	11	907	25	13	61	49
Panama	19	------	(3)	(3)	------	620	35	63	85	23
Brazil	30	(4)	(4)	(4)	(4)	1,128	−12	57	65	13
Chile	503	−1	(3)	49	48	768	14	−2	62	66
Peru	240	−8	(3)	40	40	448	−6	1	70	65
Europe	55	7	−3	4	6	10,351	893	568	992	507
Africa, total	351	31	11	31	20	1,423	104	46	170	123
South Africa, Republic of	67	−1	6	17	10	415	12	43	86	40
Far East	31	1	1	2	1	1,510	143	64	186	124
Oceania, total	70	1	5	8	3	1,463	100	83	145	57
Australia	70	1	5	8	3	1,277	99	71	127	51
All other countries [5]	211	30	3	74	70	4,224	245	22	1,186	1,006
Total all areas [6] [7]	3,350	65	66	359	293	40,645	1,888	1,565	4,572	3,059

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[1] Earnings is the sum of the U.S. share in net earnings of subsidiaries and branch profits.

[2] Income is the sum of dividends, interest, and branch profits.

[3] Less than ½ unit.

[4] Combined with other industries in source reference.

[5] "All other countries" includes other Western Hemisphere, Middle East, and International.

[6] Excludes Cuba and Soviet bloc countries.

[7] Detail may not add to totals because of rounding.

Source: U.S. Department of Commerce, Office of Business Economics, Survey of Current Business. V. 44, No. 8, August 1964, pp. 10–11.

TABLE 31.—Plant and equipment expenditures of direct foreign investments by country and major industry [1]

(Millions)

Area and country	1962 [r]			1963 [r]			1964 [2]		
	Mining and smelting	Petroleum	Manufacturing	Mining and smelting	Petroleum	Manufacturing	Mining and smelting	Petroleum	Manufacturing
Canada	$245	$300	$458	$195	$375	$535	$224	$300	$710
Latin American Republics	63	277	274	75	245	268	66	269	346
Other Western Hemisphere	32	62	7	34	62	37	54	52	14
Europe	4	494	953	5	642	1,034	4	628	1,214
Africa	69	176	12	58	164	24	55	250	75
Middle East		72	6		125	5		137	5
Far East	1	106	109	2	172	111	2	209	157
Oceania	24	76	122	29	64	139	26	50	209
International		65			40			45	
Grand total	438	1,628	1,941	398	1,889	2,153	431	1,940	2,730

[r] Revised.

[1] Data may not add to totals shown because of rounding.

[2] Estimated on the basis of company projections.

Source: U.S. Department of Commerce. Office of Business Economics, Survey of Current Business, V. 44, No. 10, October 1964, p. 10.

TABLE 32.—Sources of funds of direct (foreign) investment by United States mining and smelting industries

(Millions)

Year and area	Net income	Funds from United States	Funds obtained abroad [1]	Depreciation and depletion	Total sources
1962:					
Canada	[r] $179	$95	[r] $15	[r] $100	[r] $389
Latin America	246	−28	31	80	329
Europe	5	[r] 3	[r] (2)	1	[r] 9
Other areas	64	[r] 28	[r] 61	26	[r] 179
Total	[r] 494	[r] 98	[r] 107	[r] 207	[r] 906
1963:					
Canada	187	−24	70	114	347
Latin America	234	14	15	101	364
Europe	4	7	−1	2	12
Other areas	68	44	18	22	152
Total	493	41	102	239	875

[r] Revised.
[1] Includes miscellaneous sources.
[2] Less than ½ unit.

Source: U.S. Department of Commerce, Office of Business Economics. Survey of Current Business. V. 44, No. 10, October 1964, p. 12.

FOREIGN TRADE

Value.[10]—The 1964 crude and processed nonfuel mineral imports rose 10 percent in value over the 1963 figures. Values of imported metal ores and concentrates increased 4 percent, while those of crude nonmetallic minerals declined 6 percent. The $148 million reduction of uranium and thorium ores and concentrates imports was caused mainly by SITC reclassification. There was a notable increase of 19 percent in the value of imports of iron and nonferrous ores and concentrates. Metal imports gained 15 percent in 1964. The bulk of these gains was made in steel products and copper metal imports. Processed nonmetallic minerals rose 7 percent.

The value of nonfuel minerals exports rose 30 percent. Metallic ores and concentrates and metals exports were principally responsible for the overall gain made in 1964. The metallic ores and concentrates increased 36 percent, whereas metals gained 26 percent. Value of exported crude nonmetallic minerals rose 22 percent, while that of processed nonmetallic minerals increased only 7 percent.

Tariffs.—In 1964 the U.S. Tariff Commission reported the results of nine investigations concerning alleged injury to the U.S. minerals and processing industries by foreign imports to the United States at less than fair value under section 201(a) of the Antidumping Act of 1921, as amended. The following mineral related imports were determined of no injury or likelihood thereof: 1) Peat moss from Canada, 2) cast iron soil pipes from Australia, 3) titanium dioxide from Japan, 4) white portland cement from Japan, 5) window glass from the U.S.S.R., and 6) window glass from Czechoslovakia.

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[10] Value of foreign trade is based on United Nations SITC Revised Classification. The four- and/or five-digit SITC classification imports data are available in a U.S. Bureau of Census publication, U.S. Imports of Merchandise for Consumption (FT 125), 1964, but there are no comparable exports data available in other publications.

The Tariff Commission also determined that chromic acid from Australia, steel reinforcing bars from Canada, and carbon steel bars and shapes from Canada were being or likely to be of injury to U.S. industries. The U.S. Treasury Department is taking appropriate action.

The Sixth Round of Trade Negotiations under the auspices of the General Agreement on Tariffs and Trade—widely kown as the Kennedy Round—began in Geneva, Switzerland, on November 18, 1964. In the four months prior to November, numerous public hearings were held before the Tariff Commission and Trade Information Committee and other interagency committees to form the U.S. exception list. The list is being used in the Kennedy Round of negotiations for tariff and trade barrier reductions. Minerals and mineral processing products are included in the list. The outcome of the Kennedy Round tariff negotiations will have some significance for the mineral segment of the U.S. economy.

During 1964, the Office of Emergency Planning (OEP) had one application under consideration from tungsten mill products manufacturers under section 8 of the Trade Agreements Act, the so-called national defense clause. On July 17, 1964, OEP rejected the application by manganese-chromite ferroalloy and electrolytic manganese chromite metal manufacturers to be considered under the national defense clause.

RESEARCH AND DEVELOPMENT

The bulk of total funds for research and development has been going to a narrow segment of the industry. About 80 percent or more has been and is directed for aircraft and missiles, electronics, and chemical and machinery industries. Much of the research effort was of the end-use variety and was oriented toward defense, national security, and aerospace programs. Only a small fraction of the total research funds was directed toward studies on utilization and improvement of metals and minerals including fuels. It is generally estimated that about 5 percent or more of all research and development expenditures was spent in the minerals and related industries.

Obligations by the Bureau of Mines for research and development during fiscal year 1965 were to increase 8 percent, from $25.6 million in fiscal year 1964 to $27.7 million in fiscal year 1965. The Bureau's obligations for total research during fiscal years 1964 and 1965 were $22.6 million and $23.5 million, respectively, of which 78 percent was obligated for engineering sciences and 22 percent for physical, mathematical, biological, and social sciences.

During fiscal years 1964 and 1965, the Bureau[11] spent 72 to 74 percent of its research and development funds in applied research, 16 percent in basic research, and 10 to 12 percent in development.

During fiscal years 1963, 1964 and 1965, Bureau of Mines obligated expenditures averaged about 5 percent of total Federal obligated funds for metallurgy and material research. The Bureau maintained its fourth position in the Federal Government, following in order, the Department of Defense, the National Aeronautics and Space Administration (NASA) and the Atomic Energy Commission (AEC). In basic research, the Bureau also ranks fourth, behind NASA, AEC and the Department of Defense, in that order.

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[11] Starting in 1964, Bureau definitions of research and development were changed so research and development data are not comparable with previous years.

TABLE 33.—Value of minerals and mineral products imported and exported by the United States, by commodity groups and commodities[1]

(Thousands)

SITC No.	Commodity	Imports for consumption		Exports of domestic merchandise	
		1963	1964	1963	1964
	Metals (crude):				
281	Iron ore and concentrates	$323,206	$421,337	$76,390	$79,670
282	Iron and steel scrap	6,308	9,100	170,200	239,612
283	Ore and concentrates of nonferrous base metals	299,412	354,749	59,127	71,938
284	Nonferrous metal scrap	9,384	31,568	59,918	106,755
[2] 286	Ores and concentrates of uranium and thorium	148,311	186	981	373
	Total	786,621	816,940	366,616	498,348
	Chemicals:				
	Inorganic chemicals:				
513	Elements, oxides, and halogen salts	70,379	103,961	118,902	139,390
514	Other inorganic chemicals	54,266	36,701	60,941	76,502
[2] 515	Radioactive and associated materials	45,227	112,955	2,554	2,921
	Total	169,872	253,617	182,397	218,813
	Metals (manufactured):				
671	Pig iron, spiegeleisen, sponge iron, iron and steel powders and shot, and ferroalloys	58,211	68,919	9,415	24,555
672	Ingots and other primary forms of iron or steel	24,930	36,598	31,566	72,031
673	Iron and steel bars, rods, angles, shapes, and sections	233,034	264,604	55,868	81,855
674	Universals, plates and sheets of iron or steel	138,101	195,412	213,109	266,896
675	Hoops and strips of iron or steel	25,156	21,679	29,120	41,860
676	Rails and railway track construction material of iron or steel	1,004	1,130	19,238	10,149
677	Iron and steel wire (excluding wire rod)	55,624	66,263	14,762	20,022
678	Tubes, pipes, and fittings of iron or steel	113,925	125,434	127,174	125,389
679	Iron and steel castings and forgings, unworked, not elsewhere specified	9,397	3,164	22,329	31,763
681	Silver, platinum, and other metals of the platinum group	31,734	50,636	5,202	12,405
682	Copper	296,120	383,699	206,229	224,835
683	Nickel	163,783	157,408	23,059	30,339
684	Aluminum	194,966	200,610	118,728	151,879
685	Lead	46,169	48,584	1,074	3,991
686	Zinc	28,926	34,241	11,411	13,670
687	Tin	108,739	102,556	4,910	9,898
688	Uranium and thorium and their alloys	55	29	23,704	15,521
689	Miscellaneous nonferrous base metals employed in metallurgy	32,324	33,341	25,626	43,153
	Total	1,562,198	1,794,307	942,524	1,180,211

	Minerals, nonmetallic (crude):				
271	Fertilizers, crude	40,173	3,476	44,208	58,509
273	Stone, sand and gravel	16,051	18,905	10,479	12,054
274	Sulfur and unroasted iron pyrites	24,430	26,148	34,588	40,938
275	Natural abrasives (including industrial diamonds)	50,513	61,092	16,428	20,571
276	Other crude minerals	118,035	125,121	40,112	46,352
	Total	249,202	234,742	145,815	178,424
	Minerals, nonmetallic (manufactured):				
661	Lime, cement, and fabricated building materials except glass and clay materials	31,650	34,851	7,910	10,757
662	Clay, construction materials and refractory materials	29,856	33,621	35,837	37,322
663	Mineral manufactures, not elsewhere specified	13,592	11,597	72,126	76,353
	Total	75,098	80,069	115,873	124,432
	Grand total	2,842,991	3,179,675	1,753,225	2,200,228

[1] Because of revisions in the SITC Classifications in 1963, data for some groups are not comparable.

[2] Certain uranium bearing material, formerly classified under SITC group 286, is included in SITC group 515 effective with September 1963 statistics.

Source: U.S. Department of Commerce, Bureau of the Census. United States Imports of Merchandise for Consumption. FT 110 and FT 120 Supplement, 1963, and FT 125, 1964. U.S. Department of Commerce, Bureau of the Census. United States Exports of Domestic and Foreign Merchandise. FT 410, 1963; FT 410, 1964. U.S. Department of Commerce, Bureau of the Census. U.S. Exports by Commodity Groupings. FT 420, 1964.

TABLE 34.—Bureau of Mines obligations for mining and mineral research and development

(Thousands)

Fiscal year	Applied research	Basic research	Development	Total
1961	$15,320	$3,830	$6,386	$25,536
1962	16,210	4,045	6,715	26,970
1963	17,752	3,385	8,335	29,472
1964[1]	18,905	4,138	2,550	25,593
1965[1] [e]	20,046	4,424	3,180	27,650

[1] Data not strictly comparable with those for previous years because definitions of research and development were changed.

[e] Estimate.

TABLE 35.—Bureau of Mines obligation for total research, by field of science

(Thousands)

	Fiscal years		
	1963	[e] 1964	[e] 1965
Engineering sciences	$16,495	$17,632	$18,233
Physical sciences	4,633	4,979	5,292
Mathematical sciences	9	9	9
Total	21,137	22,620	23,534

[e] Estimate.

Source: National Science Foundation. Federal Funds for Research, Development, and Other Scientific Activities (Formerly Federal Funds for Science).

TABLE 36.—Federal obligated funds for metallurgy and material research

(Thousands)

Federal agency	Fiscal year 1963		Fiscal year 1964 [e]		Fiscal year 1965 [e]	
	Basic research	Total research	Basic research	Total research	Basic research	Total research
Department of Defense	$7,868	$93,638	$8,878	$98,403	$13,633	$107,903
Atomic Energy Commission	10,388	20,511	10,777	21,491	12,062	23,162
National Aeronautics and Space Administration	22,914	45,917	31,509	47,676	24,923	33,691
Bureau of Mines	950	8,778	975	9,387	1,000	9,534
National Science Foundation	2,336	2,336	2,500	2,500	2,900	2,900
Department of Agriculture	161	1,507	186	1,671	200	1,724
Department of Commerce	425	722	461	778	506	849
Other	107	305	205	630	308	720
Total	45,149	173,714	55,491	182,536	55,532	180,483

[e] Estimate.

Source: National Science Foundation.

DEFENSE MOBILIZATION

Defense Production Act (DPA).[12]—The Defense Production Act was extended for 2 years, from June 30, 1964, to June 30, 1966. By December 31, 1964, $2,170.5 million of the original $2,100 million borrowing authority and $108 million in supplemental appropriated funds had been allocated to the delegated agencies; this left $37.5 million in OEP reserve funds available for new programs.

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[12] Executive Office of the President, Office of Emergency Planning and General Services Administration. Report on Borrowing Authority. December 31, 1964, 78 pp. Joint Committee on Defense Production. 14th Annual Report of the Activities of the Joint Committee on Defense Production. House Rept. 1, 89th Cong., 1st sess., January 12, 1965, pp. 30-36.

National (Strategic) Stockpile Program.[13]—The Office of Emergency Planning continued work in developing a long-range disposal program and supply-requirement studies for general nuclear war and reconstruction. The results of these latter studies will be used in developing nuclear war stockpile objectives. In 1964, supply-requirement studies were completed for all stockpile materials, based on current military, industrial, and other essential needs in the event of a conventional war emergency. In this review, 107 determinations on materials in the stockpile were made. Of this total, 79 determinations were made for basic materials and 28 determinations were made in subobjectives for upgraded forms of stockpile materials. There were increases in 35 and decreases in 32 objectives, 6 objectives remained unchanged.[14]

On December 31, 1964, the strategic materials held in all Government inventories amounted to $8.4 billion at acquisition cost and $8.0 billion at estimated market value. Of this amount, the national stockpile inventory of specification-grade materials for which there are stockpile objectives totaled $5.4 billion at cost and about $5.7 billion at estimated market prices. About 80 percent of the total excess was made up of minerals and processed mineral products.

During 1964 OEP embarked on 24 new mineral disposal programs to adjust downward the excess and offgrade materials from national stockpile and DPA inventory. The major commodities involved were tin, copper, aluminum, zinc, molybdenum, nickel, and lead, in order of sales magnitude. Total stockpile disposal of mineral commodities during 1964 was $240 million, of which $160 million came from the national stockpile and $80 million from DPA inventory.

Barter Program.[15]—During 1964, the Commodity Credit Corporation (CCC) negotiated 10 barter contracts, amounting to $15 million, for strategic mineral materials. The materials involved were bauxite, metallurgical chromite, and high- and low-carbon ferrochrome. In 1964 $19 million of strategic and other mineral materials were delivered to CCC. Only two mineral commodities—refractory chromite and small diamond dies—were acceptable for barter offers in 1964.

Office of Minerals Exploration (OME).[16]—Exploration for new domestic sources of strategic and critical mineral commodities continued to be encouraged by government assistance under the program established in 1958. Activity in gold and silver exploration was the highlight of the 1964 OME program. Thirty-six contracts, representing maximum government participation of $3.2 million, were in force at yearend. There were no changes in mineral commodities eligible for exploration.

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[13] Executive Office of the President, Office of Emergency Planning. Stockpile Report to the Congress. January–June 1964, 29 pp. and July–December 1964, 26 pp. Statistical Supplement to Stockpile Report to the Congress, January–June 1964, 33 pp. July–December 1964, 35 pp.

[14] Executive Office of the President, Office of Emergency Planning. Stockpile Report to the Congress With Statistical Supplement. January–June 1964, p. 2.

[15] Executive Office of the President, Offiice of Emergency Planning. Stockpile Report to the Congress January–June 1964 29 pp., and July–December 1964, 26 pp. U.S. Department of Agriculture. Foreign Agricultural Service. Office of Barter and Stockpile. Published record. Joint Committee on Defense Production. 13th Annual Report of the Activities of the Joint Committee on Defense Production. House Rept. 1095, 88th Cong., 2d sess. Jan. 13, 1965, pp. 14–26.

[16] U.S. Department of the Interior, Office of Minerals Exploration. 12th, June 30, 1964, 10 pp. and 13th, December 31, 1964, 9 pp. Semiannual Report on Exploration Assistance.

TABLE 37.—U.S. Government stockpile disposal of mineral commodities, 1964

Commodity	Sales commitments	
	Quantity	Sales value
National stockpile inventory:		
Antimony short tons	1,135	$950,018
Cadmium pounds	23,600	70,905
Chromite, metallurgical short dry tons	2,338	23,380
Cobalt, carbonate pounds	4,701	128
Graphite (mixed, all grades) short tons	6	139
Kyanite and mullite short dry tons	1,151	20,142
Lead short tons	50,000	13,125,320
Magnesium ingots do	4,350	2,723,662
Molybdenum pounds	8,048,229	13,937,755
Nickel oxide, powder do	712,750	528,060
Quartz crystals, crude do	87,544	141,075
Talc, steatite, block and lump short tons	5	800
Tin long tons	31,178	107,184,723
Tungsten concentrates pounds	59	10
Zinc short tons	75,000	21,099,118
Total national stockpile		159,805,235
Defense Production Act (DPA) inventory:		
Aluminum short tons	49,000	23,398,903
Beryl pounds	926	150
Copper short tons	61,433	40,218,880
Cryolite, synthetic do	16,545	2,524,775
Lead do	86	22,360
Mica, skimmings pounds	14,653	1,172
Nickel do	16,783,000	13,170,216
Titanium sponge do	263,173	90,075
Tungsten concentrates pounds contained tungsten	1,100,000	809,754
Total DPA		80,236,285
Grand total		240,041,520

Source: Office of Emergency Planning. Stockpile Report to the Congress. January-June 1964, p. 10, July-December 1964, p. 9.

WORLD REVIEW [17]

World Economy.—The rising trend of the world economy begun in 1958 continued through 1964. Aggregate world economic growth in 1964 was at least 5 percent above that of 1963. The development of demand for industrial and agricultural production and trade in the developed countries during 1964 again improved.

World Production.—The United Nations (U.N.) index of free world metal mining output rose 5.7 percent in 1964. Within this world grouping, the following gains were noted: North America, 6.1 percent; Latin America, 3.3 percent; Asia, 3.8 percent; and Europe, 6.6 percent. Thus, Europe and North America were principally responsible for the overall world gain in 1964.

The U.N. index of world basic metals increased significantly by 12.6 percent in 1964. Asia, principally Japan, gained 18.8 percent; North America increased 13.1 percent, with the United States gaining 13.2 percent; and Europe rose 11.1 percent. The U.N. index for nonmetallic meneral products rose 10.4 percent wirh a 13.4 percent increase in Asia, again primarily Japan; 12.2 percent in Europe; and 7.9 percent North America.

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[17] American Bureau of Metal Statistics. Metal Statistics, 1965. June 1965, 800 pp.
Mining Journal. Mining, Annual Review. (London), 1965, 383 pp.
United Nations. World Economic Survey 1964, Part I, 126 pp.
United Nations Conference on Trade and Development. Commodity Survey, 1964. June 1965, 63 pp.

Free world production of major processed mineral raw materials recorded another overall gain in 1964. U.S. production and imports of principal minerals and metals again comprised the major portion of the world output, following closely the historical trend, and the U.S. total share of world output in these commodities was generally slightly higher than in 1963.

World Consumption.—Free world production made a vigorous gain of 13 percent in 1964. This caused world consumption of iron ore and additive metal ores such as manganese, nickel, chromite, and molybdenum used in making steel to increase.

An 8.3-percent gain in the output of the free world's heavy manufacturing (metal-using) industry and the continuous rising production of the world's automobile industry in 1964 resulted in an overall increase of 7.6 percent in world consumption of nonferrous metals.

World Stocks.—The rising consumption of free world metal-using manufacturers again outpaced world metal production, and hence, world metal stocks were further reduced in 1964. Tin was the sole exception with a 6-percent increase despite sales from the U.S. stockpile and Italian government.

U.S. stocks of aluminum declined slightly in 1964, continuing a long-term trend; stocks have declined by more than 62 percent since 1960. World stocks of blister copper did not change much during 1964, but there was a decline of 140,000 tons in producer stocks of refined copper. The U.S. stocks depletion accounted for 21 percent of the decline of the world's copper stock.

Stocks of refined lead have fallen continuously since 1961. This decline was accompanied by a fall in the U.S. stockpile because stocks were released in 1964 to relieve the problem of lead scarcity. The U.S. stockpile release was sufficient to halt the downward trend of the world's zinc stocks. Western Europe and the United States were responsible for the bulk of the decline.

World Trade.—Free world trade in iron ore in 1964 again increased; the largest gain which was recorded by Japan was followed by smaller gains in the United States and Western Europe. World trade of nonferrous metal ores reversed the 1963 decrease and registered a 13-percent gain. Lead and zinc ore trade gained 16 and 28 percent, respectively, whereas tin ore trade increased only 2 percent.

Free world trade of nonferrous metals rose 4 percent in 1964. The marked increase in aluminum trade reflects rising consumption of this metal due to accelerated growth of industrial production, particularly in the developed countries. Trade in zinc metals increased 12 percent in 1964. This increase principally reflects a rise of nearly 20 percent in Canadian exports and a 70-percent increase in exports by the U.S.S.R. World trade of lead metals rose insignificantly. The rises in United States and United Kingdom imports compensated for the decline of imports in the European Economic Community countries. Exports of blister and refined copper gained slightly in 1964 to regain the 1962 level. This overall rise in export trade reflects increases in consumption not only in the developed countries but also in the less developed countries in Latin America and Africa.

World Prices.—Despite the release of U.S. stockpile materials, the U.N. price index of nonferrous metals moving in international trade registered a substantial increase of 23 percent in 1964 and by yearend reached the highest level since the Korean war. Aluminum prices rose slowly, whereas copper, lead, tin, and zinc prices rose steeply during the year. Largely accounting for this exceptional price increase was the strong expansion of industrial activity in most developed countries which resulted in above-average demand, especially among the metal-using sectors of the electrical, general engineering, automobile, and construction industries. However, general demand influences alone are not sufficient to account for the spectacular rise in nonferrous base metal prices. Many special factors worked in the same direction, as described in the individual commodity chapters. The steel price in world trade was relatively stable but was softening owing to the 13-percent increase of world steel production in 1963, weakening world iron ore prices (a consequence of the large surplus in the world iron ore production capacity), the keen competitive market, and the launching of new large-scale iron mining projects.

The U.N. index of metal ores, which is weighted heavily with iron ores in world trade, rose only 8 percent in 1964. The stable but weak iron ore prices diluted the larger gains made in nonferrous metal ore prices. The U.N. index of minerals, which includes only fuels and metal ores, increased 2.2 percent in 1964, whereas the primary commodities index, which does not include nonferrous metals, rose only 3 percent.

Ocean Freight Rates.—The general cargo index of ocean freight rates rose 3.3 percent in 1964 over that of 1963, the mineral ores and fertilizers indexes rose 3.0 and 11.3 percent, respectively, and the coal index declined 3.9 percent.

TABLE 38.—Indexes of world production of metal mining, basic metals, and nonmetallic mineral products

(1958=100)

Year	Free world [1]	Canada and the United States	Latin America [2]	Asia: East and Southeast [3]	Europe [4]
			METAL MINING		
Weight-percent (1958) in world index	----------	34.6	13.3	7.6	15.3
1960	116	114	[r] 118	[r] 123	[r] 108
1961	[r] 119	[r] 114	[r] 116	[r] 130	[r] 114
1962	[r] 122	115	[r] 117	[r] 134	111
1963	122	114	118	132	106
1964:[p]					
First quarter	122	110	121	129	112
Second quarter	132	130	121	129	118
Third quarter	131	124	124	149	104
Fourth quarter [p]	131	120	123	142	120
Annual average	129	121	122	137	113
			BASIC METAL INDUSTRIES		
Weight-percent (1958) in world index	----------	50.6	3.5	5.3	37.8
1960	122	117	[r] 119	[r] 169	124
1961	[r] 124	114	[r] 127	202	125
1962	127	121	[r] 135	208	123
1963	135	130	142	234	126
1964:[p]					
First quarter	147	141	139	269	138
Second quarter	155	151	156	277	143
Third quarter	147	144	162	277	131
Fourth quarter [p]	160	154	NA	290	148
Annual average	152	147	NA	278	140
			NONMETALLIC MINERAL PRODUCTS INDUSTRIES		
Weight-percent (1958) in world index	----------	44.8	5.1	6.0	40.0
1960	[r] 117	115	[r] 110	139	[r] 119
1961	121	114	[r] 115	156	[r] 126
1962	128	119	[r] 120	173	[r] 134
1963	134	126	123	187	139
1964:[p]					
First quarter	131	119	129	198	136
Second quarter	154	139	132	205	167
Third quarter	156	146	139	217	162
Fourth quarter [p]	153	139	NA	227	161
Annual average	148	136	NA	212	156

[p] Preliminary.

[r] Revised.

NA Not available.

[1] Excluding Albania, Bulgaria, China (mainland), Czechoslovakia, East Germany, Hungary, Mongolia, North Korea, Poland, Rumania, the U.S.S.R. and North Viet-Nam.

[2] Central and South America and the Caribbean Islands.

[3] Afganistan, Brunei, Burma, Ceylon, Taiwan, Hong Kong, India, Indonesia, Iran, Japan, South Korea, Malaysia (excluding Sabah), Pakistan, Philippines, Thailand, and South Viet-Nam.

[4] Excluding Albania, Bulgaria, Czechoslovakia, East Germany, Hungary, Poland, Rumania, and the U.S.S.R.

Source: United Nations Monthly Bulletin of Statistics. V. 19, May 1965, pp. X–XIX.

TABLE 39.—Comparisons of world and U.S. production and U.S. imports of principal metals and minerals in 1964

Mineral	World production (thousand short tons unless otherwise stated)	U.S. production (percentage of world production)	U.S. imports (percentage of world production)	Total U.S. production and imports (percentage of world production 1964)	Total U.S. production and imports (percentage of world production 1963) [r]
Fuels:					
Coal	3,035,958	17	(2)	17	18
Petroleum (crude)__thousand barrels__	10,327,591	27	8	35	37
Nonmetals:					
Asbestos	3,540	3	21	24	23
Cement [1]__thousand barrels__	2,374,109	16	(2)	16	17
Diamonds__thousand carats__	36,285	(3)	47	47	40
Feldspar__thousand long tons__	1,770	36	(2)	36	32
Fluorspar	2,770	8	25	33	32
Gypsum	51,530	21	12	33	32
Mica (including scrap) thousand pounds__	410,000	56	4	60	62
Nitrogen, agricultural [1 4 5]	15,400	29	10	39	38
Phosphate rock__thousand long tons__	57,910	40	(2)	40	40
Potash (K_2O equivalent)	13,000	22	10	32	32
Salt [1]	108,800	29	2	31	31
Sulfur, elemental_thousand long tons__	13,800	45	11	56	57
Metallic ores and concentrates:					
Bauxite__thousand long tons__	33,145	5	31	36	36
Chromite	4,720	(3)	14	14	14
Copper (content of ore and concentrate)	5,420	23	1	24	23
Iron ore__thousand long tons__	566,716	15	7	22	21
Lead (content of ore and concentrate)	2,735	10	5	15	14
Mercury__thousand 76-pound flasks__	251	6	16	22	26
Molybdenum (content of ore and concentrate)__thousand pounds__	94,400	69	(6)	69	72
Nickel (content of ore and concentrate)	427	3	28	31	33
Silver__do__	249,500	15	21	36	38
Titanium concentrates:					
Ilmenite [4]	2,576	39	5	44	50
Rutile [4]	212	4	52	56	38
Tungsten concentrate (60 percent tungsten dioxide)__short tons__	64,900	14	3	17	12
Vanadium (content of ore and concentrate)[4]__do__	7,600	57	(6)	57	54
Zinc (content of ore and concentrate)	4,395	13	7	20	22
Metals, smelter basis:					
Aluminum	6,730	38	7	45	46
Copper	5,750	23	4	27	26
Iron, pig	350,092	25	(2)	25	24
Lead	2,825	16	8	24	22
Magnesium__short tons__	165,900	48	2	50	49
Steel ingots and castings	480,780	26	2	28	27
Tin	189	3	17	20	23
Uranium oxide (U_3O_8) [4]__short tons__	25,590	46	21	67	74
Zinc	4,055	24	3	27	27

[r] Revised.
[1] Including Puerto Rico.
[2] Less than ½ unit.
[3] None produced.
[4] World total exclusive of U.S.S.R.
[5] Year ended June 30 of year stated (United Nations).
[6] None imported.

TABLE 40.—World consumption of major nonferrous metals [1]

Commodity	Distribution of 1962 value of production (percent)	Quantum index (1962=100)	
		1963	1964
Aluminum	38.0	111	120
Copper	40.8	105	113
Lead [2]	5.6	105	111
Zinc [2]	5.6	102	105
Tin [2]	10.0	108	118
Aggregate nonferrous	100.0	107	116

[1] Consumption is based on total disappearance except where otherwise indicated. The group indexes are based on the commodities listed weighted by the values of production in 1962.

[2] Estimates for consumption totals in December 1964 based on previous months' figures.

Source: United Nations, Trade and Development Board, Committee on Commodities. Review of the Situation of International Trade in Primary Commodities. Commodity Survey 1964, June 14, 1965, p. 17.

TABLE 41.—World stocks of major nonferrous metals [1]

Commodity	Volume of stocks 1962 (thousand metric tons)	Quantum index (Previous year=100)	
		1963	1964
Aluminum [2]	127	71	98
Copper [2]	64	73	71
Lead [3]	428	86	84
Tin [4]	53	84	106
Zinc [3]	197	92	92

[1] Total of producer or exporter and consumer or importer stocks.

[2] U.S. stocks only.

[3] Consumers: Japan, United Kingdom, United States.

[4] Consumers: Canada, Denmark, France, Switzerland, United Kingdom. Producers: Congo, Nigeria, Republic of South Africa, United States, Indonesia, Malaysia, Japan, Belgium, West Germany, Netherlands, and the International Tin Council Buffer Stocks (September).

Source: United Nations, Trade and Development Board, Committee on Commodities. Review of the Situation of International Trade in Primary Commodities. Commodity Survey 1964, June 14, 1965, pp. 32–34.

TABLE 42.—World trade in major nonferrous metals

Commodity	Distribution of 1962 export value (percent)	Quantum index [1] (1962=100)	
		1963	1964 [p]
Aluminum [2]	18	113	132
Copper	60	98	100
Lead	7	93	94
Zinc	7	100	112
Tin	8	106	90
Aggregate nonferrous metals	100	101	105

[p] Preliminary.

[1] Based on world export data. The group indexes are based on the commodities listed, weighted by 1962 export value.

[2] Estimates for 1964 based on the exports of 5 major exporters: France, Norway, Austria, Canada, and the United States.

Source: United Nations, Trade and Development Board, Committee on Commodities. Review of the Situation of International Trade in Primary Commodities. Commodity Survey 1964, June 14, 1965, p. 36.

TABLE 43.—Price indexes of free world commodity trade

(1958=100)

Year	Primary commodities [1]	Total minerals [2]	Metal ores	Nonferrous base metals
1960	97	93	98	114
1961	95	92	100	110
1962	94	92	99	109
1963	100	92	96	110
1964:				
First quarter	105	93	99	118
Second quarter	103	94	102	126
Third quarter	101	95	106	139
Fourth quarter	102	96	111	156
Annual average	103	94	104	135

[1] Does not include nonferrous metals.
[2] Includes fuels and metal ores.

Source: United Nations Monthly Bulletin of Statistics. June 1965, special table C.

TABLE 44.—Indexes of ocean freight rates

(1958=100)

Year	Trip charter freight-rate indexes [1]		
	General cargo	Ore	Fertilizers
1960	111	103	97
1961	118	103	105
1962	98	79	96
1963	120	99	97
1964:			
First quarter	127	107	(2)
Second quarter	121	96	108
Third quarter	118	96	104
Fourth quarter	130	106	(2)
Annual average	124	102	108

[1] United Kingdom indexes based upon weighted average of quotations by all flags on routes important to United Kingdom tramp fleet in 1960.
[2] Rate not determined.

Source: United Nations Monthly Bulletin of Statistics. March 1965, special table F, p. XXXII.

Review of Metallurgical Technology

By Kenneth B. Higbie[1] and Rollien R. Wells[2]

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PRESIDENT LYNDON B. JOHNSON announced at midyear that the test flight of the A–11 plane, the world's first supersonic aircraft capable of flying 2,000 miles per hour, was made possible by "the mastery of the metallurgy and fabrication of titanium." Not all of the contributions made by the mineral industry in 1964 were acknowledged so widely. Yet the contributions were significant as the search continued for new and improved methods for providing metals and mineral products to meet the ever-expanding requirements of the world economy. This chapter reviews only a few of the metallurgical developments that resulted from U.S. and foreign research efforts.

MINERAL BENEFICIATION

Up-to-date theory and practice in the mineral processing field in 1963 involved subjects such as autogenous grinding, high-intensity magnetic separation, and mill control by computers. These subjects were fully discussed at the Seventh International Minerals Processing Congress held in New York City during September.

Autogenous grinding continues to draw wide interest. The grinding of rock upon itself without the use of steel or other grinding bodies has been proven to yield a satisfactorily ground product uncontaminated by foreign metals. Secondary, primary, and intermediate grinding systems are now in use. Flow diagrams for these systems are presented in figure 1. In secondary grinding operations, the millfeed is normally a rodmill product or an equivalent size from a roll crusher or primary rockmill. Grinding media, sized and removed from the ore stream ahead of the mill, are selected to have the proper size and weight to grind the millfeed. Both materials are added to the mill continuously and are considered in calculating the total feed rate. Secondary rock milling can be applied to any ore or rock containing sufficient material that is hard enough in the required size range to be used as grinding media and can be done in either wet or dry conditions.

In primary grinding—the truly autogenous system—millfeed may be either primary crusher discharge or run-of-mine ore containing material on each side of the screen analysis below the largest piece in the feed. This technique, too, can be applied in either wet or dry conditions.

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[2] Assistant director of metallurgy research.

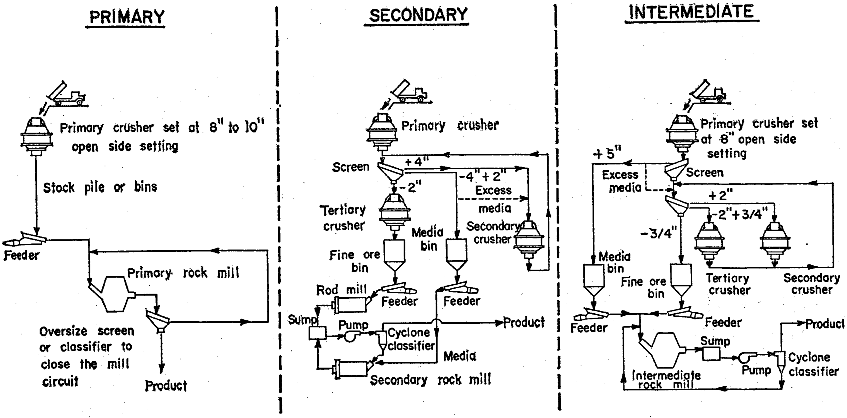

Figure 1.—Typical flow charts for three types of autogenous grinding.
(Courtesy, McGraw-Hill, Inc.)

The latest technique to be developed, intermediate autogenous grinding, is a compromise between the primary and secondary systems. The ground ore feed is very coarse and almost approaches the size of run-of-mine material. As in the secondary application, ore used for grinding media is sized and removed from the ore stream in the crushing plant. What gives the intermediate system its advantage over the other two is that it eliminates both rod and ball milling while still using sized media for sized feed. It has been claimed that the cost saving by eliminating rod and ball milling is approximately 65 to 70 percent of the cost of ball and rod wear. Proponents of the intermediate system maintain that (1) the crushing action in a primary autogenous mill is generally inefficient since it is an uncontrolled mixture of impact and abrasion; (2) secondary autogenous grinding has been successfully applied for many years, but it needs a rodmill, a fine crushing stage, or a primary autogenous unit for feed preparation; (3) intermediate autogenous grinding can use power as efficiently as rod and ball milling; and (4) the intermediate system can be applied to any ore or rock, provided the material in the size fraction to be used as media is suitable.

Bath Iron Works Corp.'s Pennsylvania Crusher Division designed an autogenous unit that was particularly suitable for reducing taconite, manganese, and chromite ores and other hard-to-grind material down to between 100 and 325 mesh in one operation. Called the vertical impact pulverizer (VIP), Bath's machine not only effectively grinds the tough ore but reportedly does so with greatly reduced equipment wear and grinding costs. Material enters VIP through a vertical feedpipe, hits a rotating impeller that accelerates it to 2,100 to 3,600 revolutions per minute, and then is hurled into a counter-rotating bowl to strike against previously discharged material. After impact, the material overflows the recess and slides up the sides of the bowl's conical portion. Smaller particles are carried upward by an air system, and oversized material flows into recirculating vanes and back to the impellers. The valuable features are the counter-rotation that increases the speed of particle impact and the band of material that protects the bowl surface from direct impact by the high-velocity particles.[3]

The Warren Springs Laboratory in the United Kingdom reported that continued developmental studies on a pulsed shaking table resulted in improved mineral separations. This device combines conventional tabling action with a modified jigging action induced by pulsation of water through a porous table deck. Pilot-scale tests have indicated that a twofold to threefold improvement in metallurgical performance and a twofold to fivefold increase in throughput can be obtained, campared with results using a normal shaking table of equivalent size.

Low-intensity magnetic separators continued to be the principal devices employed for concentration of magnetic ores, although both wet and dry high-intensity magnetic separators received increased attention. At least three types of wet high-intensity concentrators have been proposed. Each has been studied in laboratory and pilot plant operation and is awaiting decision on incorporation in full-scale production facilities. Substantial research is being conducted to improve the separation efficiency of the machines and to prevent the entrapment of nonmagnetic material in stringers of highly magnetic particles. Several magnet poles have been examined, including one composed of freely moving spheres. One pole surface that is reported to produce good results consists of short steel wires set perpendicular to the plate surface and embedded in a synthetic resin. Results indicated that a relationship exists between the diameter of the steel wire and the size of mineral particles that can be separated. One semicontinuous high-intensity magnetic separator was adopted for pilot mill production of a 98-percent-pure wollastonite from a mineral concentrate containing 30 percent magnetic contamination.

A process for treatment of complex low-grade nonmagnetic iron ores was developed by the Federal Bureau of Mines at its Minneapolis Metallurgy Research Center. Finely ground dispersed pulp is treated with a starch derivative to effect selective flocculation of the iron materials. Settling of the flocculated iron particles allows removal of a low-grade slime product. Subsequent treatment of flocculated sands by anionic silica flotation methods results in improved grade, recovery, and froth character when compared with similar materials not treated by selective flocculation.[4]

Two Canadian patents issued describe a new development called the flotation column, which permits flotation of various minerals at higher efficiencies than conventional flotation cells. The flotation column was developed for iron ore concentration but is now being tried on copper sulfide ores. Briefly described, the column is a vertical tube, with water at the top and air at the bottom; the feed slurry enters in the middle of the tube. As the air rises, it passes through a diffuser to form bubbles that carry the desired constituent of the slurry to the top. The product-laden bubbles that may contain fine gangue particles are washed in the downward path of the water before they overflow from the column's top. Rejected material exists with the underflow. Inventors of the column technique said that conventional cells increase the probability of trapping gangue in the froth bed, because slurry suspension is maintained by air or impellers; thus no concentration occurs below the froth layer. The column establishes an increasing concentration gradient from bottom to top of collector-conditioned mineral, reducing chances of mechanically locking the undesired solids in the overflow. Counter-current washing also helps strip unwanted solids from the rising bubbles. Use of the column promises higher efficiency, 90 percent less floor space, savings in power costs, and ease of operation.[5]

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[3] Bond, Fred C. An Expert Reviews the Design and Evaluation of Early Autogenous Grinding Systems. Eng. and Min. J., v. 165, No. 8, August 1964, pp. 105–111.
Domaas, Finn B. New Ideas, Equipment Spur Autogenous Boom. Eng. and Min. J., v. 165, No. 10, October 1964, pp. 91–95.

[4] Frommer, D. W. USBM. Tests on Selective Iron Flotation Point Way to Greater Recoveries. Min. Eng., v. 16, No. 4, April 1964, pp. 67–71, 80.
Wasson, P. A. Concentration Review. Min. Eng., v. 17, No. 2, February 1965, pp. 106–108.

The copper segregation process, including the direct firing technique developed by the Bureau of Mines, was being studied on a pilot plant scale at the Colorado School of Mines Research Foundation to treat mixed oxide and sulfide ores from Mauritania, Africa. The investigation was supported by United States, Canadian, and French mining companies in association with the Mauritanian Government. Sufficient data are expected from the study to allow the design and construction of a 3,000-ton-per-day plant.

A process under study by the Bureau of Mines promises to create acceptable blast-furnace feed from two relatively useless materials, nonmagnetic taconite and waste automobile bodies. It had been known that the nonmagnetic mineral could be converted to the magnetic form by roasting with carbon, but the cost is considered excessive under present conditions. The Bureau found that by blending and calcining the taconite in a conventional rotary kiln with 4- to 6-inch pieces of autobody scrap, already a good form of metallic iron, the scrap acts as a reductant to reduce the excess oxygen present in the taconite, thereby converting it into a highly acceptable ore relatively free of contamination. The resulting material could then be beneficiated by normal magnetic separation methods. Nonmagnetic semitaconite (31.3 percent iron) was processed at a rate of 500 pounds per hour to yield magnetic concentrates containing 60 to 63 percent iron while rejecting a waste product containing approximately 9 percent iron. Unoxidized scrap metal was reclaimed and recirculated to hold the new scrap required to a near-theoretical 30 pounds per hour.[6]

Michigan Technological University was studying a process to improve the grade and structure of conventional Michigan iron ores through use of a small continuous experimental reactor. Tests were conducted on several types of ores to determine the optimum processing conditions to yield reduced agglomerates containing 75 to 80 percent iron suitable for blast furnace feed. The ultimate aim is to produce reduced agglomerates even higher in iron for full-scale electric furnace and cupola tests. The program was sponsored by the

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[5] Des Ormeaux, Dollard. Extraction of Oil from Tar Sand. Canadian Pat. 680,576, Feb. 18, 1964.

———. Separation and Recovery of Ores. Canadian Pat. 694,547, Sept. 15, 1964.

Engineering and Mining Journal. Flotation Column Due for Mill Scale Tests in Canada. V. 166, No. 1, January 1965, pp. 76–78.

[6] Fine, M. M., and N. B. Melcher. Ore-Scrap Magnetic Roasting. J. Metals, v. 16, No. 9, September 1964, pp. 709–714.

State of Michigan, the Federal Area Redevelopment Administration, and Cleveland-Cliffs Iron Co.

A process was studied to produce iron powder from sedimentary, oolitic ores containing 30 to 35 percent iron which are found in the Clear Hills region of northwestern Alberta, Canada. The Peace River Mining and Smelting Company, Ltd. constructed a pilot plant to produce a high-purity (99 percent) nonpyrophoric iron powder suitable for compacting and shaping by standard powder metallurgy methods. For preparation of the powder by the new technique, the ore is first roasted with coal in a reducing atmosphere to convert the ferric oxide and other iron-bearing materials to metal and ferrous oxide. Then the roasted material is dissolved in hydrochloric acid and filtered to remove the insoluble impurities. Hydrated ferrous chloride is crystallized, and the crystals are separated. Finally, the ferrous chloride crystals are dried and reduced in a hydrogen atmosphere at elevated temperatures to produce iron powder and hydrogen chloride.[7]

A marked increase was noted in the growth of pelletizing as a method of preparing iron ore concentrates for blast furnace feed. United States Steel Corp. indicated it would build a plant to produce 4.5 million tons of iron ore pellets annually. This would be U.S. Steel's first major commercial venture into pelletizing. Before this, it has largely depended upon sinter for use in its blast furnaces. Other firms placed on stream or began construction of pelletizing plants which incorporated the latest technologies of pelletmaking. Additional plants in the taconite mineral area of Minnesota were announced late in the year after the State's voters approved an amendment to its constitution providing for new tax treatment on taconite property.

Construction was started on a new 1.6-million-ton gratekiln pelletizing plant for Eveleth Taconite Co., owned jointly by Ford Motor Co. and Oglebay Norton Co. The new plant will process magnetic taconite from northern Minnesota containing 25 to 30 percent iron in pellets containing some 63 percent iron. This system will include a traveling grate 113 feet long, on which green pellets will be preheated; a rotating kiln 18.5 feet in diameter and 120 feet long, in which the pellets will be hardened at about 2,300° F and a 50-foot-diameter cooler.

Near Sullivan, Mo., the 2-million-ton Pea Ridge pelletizing plant of Meramec Mining Co., started operation. Nearby ore is mined by underground methods, crushed in two stages, ball milled, and concentrated by magnetic means. Flotation techniques are used to recover iron from the nonmagnetic material. Concentrate is formed into three-eighths to one-half inch balls and fed into shaft-type pellet-hardening furnaces. Heated by fuel oil burners, these furnaces achieve a temperature of about 2,400° F and produce hardened pellets containing some 68 percent iron which are discharged into coolers.[8]

Hanna Mining Co.'s new 1.5-million-ton pellet plant at Groveland, Mich., came into production in the spring of 1964. Incoming concentrate is wet-ground to 75 to 80 percent minus 325 mesh and slurried to a desired thickness; bentonite is then added as a binding agent, and the mixture is fed to balling drums. Sized green pellets, discharged from the balling drums, are conveyed to a Dravo-Lurgi roll feeder to be fed onto the pelletizing machine. Pellets in 12-inch-thick beds are placed on pallets which move through drying zones, preheated to 1,800° F, and are eventually fired at 2,400° F until properly hardened. The pellets cool to 250° F and are discharged onto a Dravo-Scheuck vibrating screen; the sized product is sent to storage.

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[7] Journal of Metals. Fe Powder From Low Grade Ore. V. 16, No. 8, August 1964, p. 617.

[8] Journal of Metals. Pelletizing Saving U.S. Iron-Ore Industry. V. 16, No. 7, July 1964, p. 548.

The first pelletizer for nickel ores was being installed in New Caledonia for the Société le Nickel. Built by Polysius G.m.b.H., the facility provides all machines and equipment for enrichment of garnerite and for the preparation of pellets. Approximately 1.5 million tons of pellets will be processed per year by the LEPOL process, details of which were not announced.

PYROMETALLURGY

At the same time that changes have been made in ore beneficiation, to yield better starting materials, the steel industry has been placing prime attention on pyrometallurgical reduction processes and attempting to increase the overall efficiency of the various techniques of making steel. Production of metal by the basic oxygen furnace (BOF) process surpassed that by the electric furnace for the first time, and represented 12 percent of total 1964 steel production. It appears likely that within 15 years production by the BOF process will exceed that by the open-hearth method.

These changes in process technology are already evidenced by the steel plants' changing demand for hot metal, scrap, refractories, heavy fuel oil, ore pellets, fluxing materials, and other supplies. As the BOF process becomes the major factor in the steel industry, requirements for ore, molten pig iron, and some kinds of refractories should increase, while requirements for scrap, heavy fuel oil, and a few other goods may drop severely.

The possible decline in the use of scrap stimulated numerous studies to determine how more of it can be incorporated with oxygen steelmaking methods. Preheating of scrap before charging was looked upon with favor. This practice, determined to be beneficial by Bureau of Mines research conducted in the late 1940's, has not been widely accepted by the industry. As the result of studies supported by the natural gas companies, Chemetron Corp. developed a preheating burner which reportedly would permit the scrap content in a heat of steel to be increased by 60 percent. The 53-foot-long water-cooled burner heats 60 tons of scrap from room temperature to more than 1,000° F in less than 10 minutes, thus materially speeding production of finished heat. Oxygen is consumed at a rate of 5,000 standard cubic feet per minute and generates a heat output of 200 million Btu per hour.

The British Iron and Steel Research Association (BISRA), too, developed a special burner which fed additional fuel oil and oxygen when cold scrap was added to the furnace. With this burner it was believed that up to 100 percent of the scrap could be fed cold. In operation an analysis is made to adjust the oxygen and fuel oil rates after the scrap reaches the molten stage. At appropriate temperature and pressure, which are automatically controlled, the burner is cut out prior to tapping.

A method of making steel from all cold charges by oil-oxygen burners was developed by BISRA also. This fuel-oxygen-scrap process (FOS), which has been studied in ½- and 5-ton experimental furnaces, appears to be commercially feasible. The FOS process is carried out in a cylindrical vessel electric furnace. The charge—normally scrap steel, lime, and carbon—is basket-charged, the roof is replaced, and the Toroidal Burner is ignited. As the charge melts, the burner is lowered until a molten pool forms on the furnace hearth. The burner is withdrawn gradually to extend the molten pool and melt the remaining scrap. At this stage, the bath is sampled, and the oil and oxygen rates are adjusted to remove carbon and raise metal temperature so that the correct composition and tapping temperatures can be achieved simultaneously. The heat is then blocked, the necessary additions are made, and the furnace is tapped. To produce 1 metric ton of finished steel required 22 gallons of oil, 6,000 cubic feet of oxygen, and 1½-hour charge-to-tap time. Ingot yields of 90 to 91 percent on rimming carbon and low-alloy steels were made. Both light and heavy scrap could be used, and, as an alternative carburizing agent, pig iron up to at least 50 percent of charge was employed. One of the unusual features of this oxygen-employing process was the absence of red fume. Exhaust-stack sampling showed dust concentrations over whole heats of 0.01 to 0.02 grain per cubic foot. An economic analysis of the FOS process, under British conditions, indicated that, in a plant suitably designed for annual output of 70,000 metric tons or more, the cost of ingot making would be $2.10 to $2.80 per ton less than with electric steelmaking of similar scale.[9]

A new experimental blast furnace, operated under the direction of the Federal Bureau of Mines in cooperation with Blast Furnace Research, Inc., was blown in during April 1964. Blast Furnace Research, Inc., is a nonprofit organization representing 22 ironmaking companies in the United States and Canada. The new furnace, which replaced a research unit that had been in service 5 years, is a high-pressure, high-temperature unit designed to operate at levels well above the upper limits of commercial experience. Top pressures will be as high as 40 to 45 pounds per square inch gage, and hot blast temperature will approach 3,000° F. Industry considers pressures of 10 pounds per square inch gage high, and hot-blast temperature of 2,000° F is, in most cases, yet to be achieved. Initial operation of the furnace resulted in temperatures of 2,600° F through use of material gas burners to heat the two refractory-sphere-packed stoves which provided preheated air to the furnace. An important purpose of the furnace is to provide operators with the data necessary to derive the best answers for an individual plant.[10]

Direct iron processes continued to receive attention. A Canadian oil firm was building a pilot plant to study a process for reducing iron ore to the metal, which was developed by Esso Research and Engineering Co., Linden, N.J. The system uses liquid or gas fuels instead of coke as the reductant. Patents issued to the firm indicate the process involves a two-stage direct reduction of the iron ore in a fluidized-bed system. The first stage is used to reduce magnetite and ferric oxide to ferrous oxide; in the second stage the ferrous oxide is converted into sponge iron. Steam reforming is supposed to supply the reducing gases used in each stage.

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[9] Journal of Metals. FOS Process Licensed. V. 16, No. 2, February 1964, p. 143.

[10] Sheatsley, L. L., and H. G. McWalter. The Bruceton Experiments. Blast Furnace and Steel Plant, v. 52, No. 2, October 1964, pp. 15–18.

The development of vanadium carbide by Union Carbide Corp. has been followed by its wide acceptance as a replacement for ferrovanadium in the preparation of vanadium steels. The new product has two major attractions, it is prepared from high-purity vanadium salts and contains few harmful impurities, and its market price is 15 to 20 percent less than that of ferrovanadium.

The use of oxygen in making metals was extended to the copper industry. A patent issued to Kennecott Copper Corp., calls for the addition of oxygen into the reverberatory smelting operation for copper. It was found that both the roasting and the smelting reactions taking place on the exposed slopes of the banked charge are greatly enhanced if air, oxygen-enriched air, or essentially pure oxygen is blown onto them after they have become hot and reactive from the customary reverberatory procedure. Since the resulting increased temperatures are sufficiently high in the furnace areas where the smelting takes place, preliminary roasting of the ore or concentrate is unnecessary. Other advantages claimed for the method were (1) the production of a rich gas suitable for the production of sulfuric acid, (2) increased smelting rate, and (3) control of the matte grade by the elimination of more sulfur and the slagging of more iron during the smelting stage.[11]

An unusual method for carrying out chemical reactions at high temperatures was developed by researchers from Battelle Memorial Institute, Columbus, Ohio. By passing an electrical current through a fluidized bed of electrically conductive particles, they heated the bed contents of a graphite tube to 5,000° to 8,000° F for extended periods. The graphite vessel served as one electrode, and the other electrode was immersed in the bed material. Reactions believed possible with the method include chlorination of zirconium oxide, production of elemental phosphorous from phosphate shales, carbothermic reduction of metallic oxides, and formation of metallic carbides and nitrides.

HYDROMETALLURGY

Many minerals benefited from improvements in recent hydrometallurgical techniques of recovering the valuable metallic contents. A breakthrough in the processing of molybdenum ores was announced by Climax Molybdenum Co. A process was developed whereby metal could be recovered from molybdenum oxide ore that previously was considered valueless. By processing in cyclones the waste molybdenum oxide tailings obtained from the conventional flotation process for sulfide ores, the molybdenum content of the slimes can be increased to between 0.074 and 0.125 percent, some three to five times that of the original feed. Part is a classified slime, and part comes from attrition grinding of the sand. The aim is to recover 65 percent of the molybdenum oxide as a slime while rejecting the balance in three-quarters of the sulfide flotation tailing. In the chemical treatment of this concentrated slime, acid leaching will be followed by absorption of the dissolved moly-salts with activated pellets of charcoal. This takes up to 18 hours and about 20 pounds of charcoal per pound of molybdenum. The loaded charcoal is removed by screening, water-washed, and then stripped with ammonia. Phosphorus is precipitated, and the solution is evaporated to crystallize ammonium molybdate. This is then roasted to yield annular molybdenum oxide.

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[11] Journal of Metals. Copper Smelting With Oxygen. V. 16, No. 2, February 1964, p. 146.
Zimmerley, Stuart R., Reverberatory Smelting Method and Apparatus. U.S. Pat. 3,102,806, Sept. 3, 1963.

The Bureau of Mines reported results of research on a process which may enable small copper producers to prepare a directly marketable high-grade copper powder product by means other than the usual smelting and electrolytic purification process. Fine particles of cement copper are first produced in a drum precipitator in which iron nails or wire are gently tumbled with the copper leach solutions. Excess iron in the resulting cement copper is removed by chemical digestion in a copper sulfate solution; the powder is collected by filtration and subjected to an atmosphere of hydrogen gas in which any copper oxide is reduced; and then the copper oxide is sintered to densify the powder. A grinding step for the sintered copper is provided to yield a powder product of the desired size. Treatment of copper leach solutions from three different sources resulted in copper powders 99.2 to 99.8 percent pure, apparent densities of 1.97 to 2.25 grams per cubic centimeter, good powder flow rates, and a size distribution of 54.9 to 60.1 percent minus 325 mesh material.[12]

A similar process, designed to avoid the use of ammonia in chemical refining of copper, was installed by the Bagdad Copper Corp. in its new plant at Bagdad, Ariz. Initially developed by Chemetals Corp., New York, the process utilizes hydrogen gas as a reductant, thereby making it unnecessary to produce ammonium sulfate as a byproduct. The process starts with cement copper powder produced by reduction of copper sulfate leaching solutions with iron. The powder contains 84 to 88 percent copper. It is washed off the iron, dried, and leached at 140° to 180° F in a sulfuric acid solution through which air is blown. After filtering the effluent from the leaching step to remove undissolved impurities, mostly ferric hydroxide and silica, the solution is preheated and reduced with hydrogen in an autoclave at 300° F and 400 pounds per square inch. Polyacrilic acid is added to the autoclave to help prevent copper from depositing on the internal surfaces of the autoclave. After the reduction step, the powder is centrifuged to remove excess sulfuric acid, dried, sintered, ground, and sized to produce the finished powder which can be melted or employed in powder metallurgy processes.

Kennecott Copper's newly developed copper precipitation cone reportedly worked extremely well in pilot scale tests. Originally designed to remove copper from 1,000 gallons per minute with powdered iron, with slight alterations the pilot cone has treated as much as 4,000 gallons per minute and uses any clean iron metal from powder to scrap sheet. With proper control the precipitated copper is in the form of fine rounded pellets rather than the red-brown flake and slime traditionally obtained from iron-precipitated solution. Contaminating salts are readily removed with a single water wash, and the resulting product contains 95 to 98 percent copper.

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[12] Groves, R. D. Preparation of Copper Powder From Leach Solutions After Precipitation With Iron. BuMines Rept. of Inv. 6486, 1964, 23 pp.

The Israel Mining Industries, Tel-Aviv, Israel, developed a solvent extraction process for recovering copper metal ions from sulfate leach solutions. The process, being studied on a 10-gallon-per-minute pilot plant scale by Chemetals Corp., utilizes a selective solvent consisting of kerosine and bromine lauric acid. Concentration of copper in the sulfate leach solution can range from 8 to 30 pounds per 1,000 gallon. The copper is removed from the solvent by a strong acid. Impurities are eliminated by careful control of pH in the extractor. The pilot plant is using a disk contractor; its elements rotate in compartments formed by splitting a cylindrical tank in half and laying it on its side. Weirs control the flow of liquids from one compartment to another, and the disks rotating within each compartment provide good liquid-liquid contact without forming emulsions.

A new liquid ion exchange process for recovering copper from leaching liquors was developed by General Mills Inc. The standard ammonia leach method requires concentrations of about 5 percent copper before precipitation; in contrast use of LIX–63 ion exchange media reportedly removes copper ions from weak solutions.

Traditionally, titanium dioxide for pigment has been produced by a sulfate leaching method using a relatively low-grade ilmenite as starting material. In recent years, the trend has been toward wide acceptance of a lower cost chloride process. The latter, however, demands a high-grade feed. Now the Illinois Institute of Technology Research Institute (IITRI) has reported its investigation of a new process which produces titanium tetrachloride as pure as the high-quality product of the chlorination process but which utilizes the low-grade feed material of the sulfate process. As in the sulfate procedure, ilmenite ore is pulverized and dissolved in sulfuric acid. The titanyl sulfate liquor, low in iron, is then charged to a saturator and treated with anhydrous hydrochloric acid. Any iron that remains is converted to ferric chloride, precipitated from the solution, and extracted by centrifugation. An insoluble potassium chlorotitanate is precipitated from solution by addition of solid potassium chloride. Remaining impurities stay in solution, because the complexing step is specific and quantitative in that only the titanium reacts. The complexing step is the prime feature of the process. The complex, potassium chlorotitanate, decomposes completely on heating, giving solid potassium chloride, which is recycled to the complexing step, and titanium tetrachloride vapor, which is condensed. After a single purification step, the titanium tetrachloride can be oxidized to titanium oxide, with chlorine gas as a coproduct.[13]

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[13] Chemical & Engineering News. New Route to $TiCl_4$ May Help Makers of Sulfate-Route TiO_2. V. 42, No. 12, Mar. 23, 1964, p. 47.

ELECTROMETALLURGY

Efforts to improve the technology of making high-purity beryllium metal have tended to concentrate upon fused-salts electrolysis. The Bureau of Mines released a report that detailed the operation parameters of an electrorefining cell designed to recover high-purity beryllium from scrap metal. Investigation of the operating variables, such as electrolyte composition, temperature, cell voltage, cathode current density, and cell geometry, led to the development of a prototype cell for the studying of difficulties encountered in the scaleup of a laboratory process. In the prototype cell studies, scrap beryllium chips nominally 96 to 97 percent beryllium were electrorefined in a LiCl-KCl-$BeCl_2$ electrolyte yielding metal containing 700 parts per million carbon, 610 parts per million oxygen, 800 parts per million chloride, 30 parts per million hydrogen, and less than 600 parts per million total metallic impurities. Average cathode current efficiency was 96 percent. In subsequent tests recycling of undissolved anode feed was shown to be possible.[14]

Another report showed the effect in purity increase by a two-cycle electrolysis. After recycling once-deposited metal, the metallic impurities were reduced to below the spectrographic determination limits for all metals except calcium which was 35 parts per million. Additional studies by the Bureau have yielded beryllium metal by electrolysis or beryllium oxide from a fused salt of potassium-lithium-fluoride. Analysis of the metal beads produced showed a total metallic impurity content lower than in beads obtained commercially by the magnesium reduction of the fluoride.[15]

Acceptance of the fused-salt technology as a practical method for making beryllium metal was evidenced by the expansion of the beryllium industry during the year when Beryllium Metals & Chemicals Corp.'s plant at Bessemer City, N.C., went successfully on stream. The company completed a contract with Union Carbide Chemical Corp. to recover valuable metal from a large quantity of beryllium scrap by the fused-salt electrolytic process. The Anaconda Company was also studying the electrolytic process for making beryllium metal. In conjunction with Péchiney, Compagnie de Produits Chimiques et Electrometallurgiques, it was operating a pilot plant in Anaconda, Mont., to permit the development of operating data while producing limited quantities of the metal. The company plans to combine this effort with its other research programs designed to recover beryllia and other compounds from beryllium minerals found in Nevada.

The U.S. Atomic Energy Commission (AEC) has developed another electrolytic technique which utilizes a liquid mercury cathode, a molten sodium chloride-beryllium chloride electrolyte, and a cell temperature of about 330° C. The beryllium is recovered from the mercury cathode in powder form with a particle size of 5 to 8 microns. The product has an oxygen content of less than 1 percent and a low metallic impurity content. The process was being investigated by General Astrometals Corp. on large laboratory scale under sponsorship of the National Aviation and Space Administration. It has not been tested on pilot plant or industrial scale as yet. The process is reported to be applicable to uranium, titanium, zirconium, thorium, and any metal oxide which is at least as stable as chromium oxide.[16]

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[14] Wong, M. M., and J. E. Klosterman. Electrorefining Beryllium—Operation of a Prototype Cell. BuMines Rept. of Inv. 6489, 1964, 17 pp.

[15] Wong, M. M., and D. A. O'Keefe. Electrorefining Beryllium—Two-Cycle Electrolysis. BuMines Rept. of Inv. 6570, 1964, 8 pp.

Péchiney Central Research Laboratories, Grenoble, France, made very high purity beryllium metal by the fused-salt electrolytic reduction of $BeCl_2$. The initial product (SR grade) is sufficiently pure to qualify as nuclear-grade metal and is purer than the magnesium-reduced metal. The metal can be refined as many times as desired; each successive refinement produces a somewhat purer metal. There are hopes that metal containing less than 100 parts per million oxygen, 10 parts per million carbon, and not more than 5 parts per million for all other impurities can be so produced.

The Bureau of Mines investigated both the electrowinning and electrorefining of uranium metal during the year. The metal was electrowon at 99.8 percent purity from the oxide, employing uranium, lithium, and barium fluorides as the electrolyte in a fused-salt compartmented cell operated above 1,200° C. Tests indicated that the two conditions requisite to obtaining complete consolidation of the product were temperature in excess of 1,300° C and elimination of oxide materials from the vicinity of the metal product.[17]

The AEC authorized Mallinckrodt Chemical Works to build a pilot plant facility in which the Bureau's basic process was to be investigated further to obtain more data on which the overall economics of the process could be evaluated. The study was completed during 1964, and a decision to proceed into a large-scale production operation was awaited. In a similar manner, the United Kingdom Atom Energy Authority has constructed and was operating uranium electrowinning cells based on the Bureau process to gather sufficient technical and cost information to determine if the electrolytic preparation of the metal is more economical than the current practice of obtaining the metal through magnesium reduction of the fluoride.

MATERIALS

The first successful test flight of a cesium ion engine rocket was made in August 1964 in a suborbital shot. It was reported that this type of engine has decided payload advantages over chemical and nuclear systems. The long lifetime, steady thrust, and high reliability make cesium-propelled ion engine rockets particularly suitable for synchronous satellite position control. In an ion engine, cesium is vaporized in a boiler before being pressure-sprayed through a special heated grid of porous tungsten. During this operation some electrons are removed leaving positively charged cesium ions. They are accelerated to some 300,000 miles per hour by the application of high voltage and exhausted through an orifice similar to a rocket nozzle, providing a small but constant thrust making possible high vehicle speeds in outer space.

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[16] Kopelman, B., and R. B. Holden. Electrolytic Process for Producing Metals. U.S. Pat. 2,987,454, June 6, 1961.

[17] Kesterke, D. G., D. C. Fleck, and T. A. Henrie. Direct Electrolysis of Uranium Dioxide to Uranium Metal in Fluoride Melts. BuMines Rept. of Inv. 6436, 1964, 12 pp.

An improved form of molybdenum with significantly greater high-temperature performance has been announced by National Research Corp. Developed by Metallwerk Plansee, Austria, this product, known as HT molybdenum, is claimed to retain its ductility after exposure for appreciable periods at temperatures as high as 3,600° F, whereas conventional molybdenum is limited to about 2,000° F, since it becomes brittle when the temperature is raised by 100° to 200° F. The metal retains its ductility even after recrystallization. It is available in wire and ribbon form.

An improved form of primary nickel in strip form for coinage applications was developed by the International Nickel Company of Canada, Ltd. Known as electronickel strip, it is of uniform gage and is comparable to wrought nickel in mechanical properties and ease of fabrication. Produced by a new process, direct hot rolling of specially prepared electrolytic cathodes, the nickel strip has only to be cold-rolled to the desired final thickness for final coin stamping. Thus the standard processes of melting of raw metal and subsequent hot rolling are eliminated, reducing the cost of preparing coins about 30 percent.

The tendency for tantalum to develop excessive grain growth when subjected to temperatures above 1,200° C, which results in it being more susceptible to oxygen embrittlement, was greatly retarded by a new vacuum melting and processing technique developed by National Research Corp. Normal tantalum exhibits progressively larger grain sizes when heated above 1,200° C. The new product, designated SGS for stable grain size, exhibited a grain size of only 0.002 inch after a 50-hour exposure to 2,100° C at 2 to 10 microns of pressure, about 1,000 times smaller than normal tantalum grain size under the same conditions. SGS tantalum's recrystallization temperature is about 2,000° C, compared with 1,200° C for conventional tantalum. At 1,650° C, SGS tantalum has an ultimate tensile strength of 10,000 pounds per square inch, compared with 3,400 pounds per square inch for standard tantalum.[18]

A new type of maraging steel for service at elevated temperatures was developed. Said to combine most of the desirable characteristics of established maraging steels, including low distortion and dimensional changes and good machinability and weldability, the new steel has a yield strength of 180,000 pounds per square inch and a stress-rupture life of 100 hours or more when subjected to a stress of 100,000 pounds per square inch at 1,000° F. Optimum properties at 1,000° F were obtained from the alloy, which contains 15 percent nickel, 9 percent cobalt, 5 percent molybdenum, 0.7 percent aluminum, 0.7 percent titanium, and the balance iron.

A new alloy, designated Hastelloy alloy G, was developed by Union Carbide Corp. for use with hot sulfuric and phosphoric acids. It was found to be resistant to both oxidizing and reducing environments and to stress corrosion cracking. A corrosion rate of only 31 mils per year in boiling 20 percent sulfuric acid was noted. Composition of the new alloy is 22.25 percent chromium, 0.50 percent tungsten, 19.50 percent iron, 0.03 percent carbon, 0.35 percent silicon, 1.30 percent manganese, 6.50 percent molybdenum, 2.00 percent copper, 2.12 percent columbium and tantalum, and 45.45 percent nickel.

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[18] **Journal of Metals. Ta Resists O_2 Embrittlement. V. 16, No. 8, August 1964, p. 618.**

The invention of glass which darkens on exposure to light and clears again when the light fades was reported early in the year at a meeting of the American Physical Society. The new glass contains silver halides in microcrystal form, although compounds of titanium and cadmium may also be used. The glass is the first photochromic material that retains indefinitely the ability to darken quickly and then clear. Previous materials lost this characteristic in a short time. During 2 years of testing through thousands of darkening-clearing cycles, the new glass retained its versatility. Wave lengths that produce the darkening in the glass are typically the near ultraviolet.

The yttrium aluminum garnet doped with neodymium was found to be a good solid state material which would support continuous wave laser action, could be optically "pumped" with a tungsten filament light source, and could operate at room temperature with common tapwater as the only coolant needed.

A "practical" continuous wave garnet laser which has reportedly developed 300 milliwatts is now commercially available as the result of work done for NASA's Marshall Space Flight Center by the Linde Division of Union Carbide Corp.

Manufacture of a more efficient color television tube became possible during 1964 owing to the development of two new phosphors, europium-activated yttrium orthovanadate and europium-activated yttrium oxide. The new rare earth red phosphors are said to provide 40 percent greater brightness as well as better color fidelity than the previously employed silver-activated zinc-cadmium sulfide. Imperfect performance of the red phosphor had handicapped improvement of color television rendition. The three phosphors used conventionally are all silver-activated sulfides of zinc containing varying amounts of cadmium. The blue phosphor has no cadmium; the green has a zinc-to-cadmium ratio of 72 to 28; and the red, a ratio of 21 to 79. The red sulfide phosphor's emission was somewhat shaded toward the orange and was not a bright red as is the new europium phosphor.[19]

Fluorine and fluorine compounds have been utilized as gas media for filling a newly developed photoflash bulb. It was found that, by filling the bulb with fluorine or such compounds as OF_2 or NF_3 instead of the usual oxygen charge, the flash would produce up to 50 percent more light than present bulbs. Color temperature would be about 4,600° K, compared with about 3,900° K in present bulbs. In principle, the burning flash bulb is a thermal radiator. The heat of reaction of the metal wool, usually zirconium, and the gas raises the temperature of the reactants and reaction products to a point where they radiate energy. At normal temperature and pressure, the heat of reaction when zirconium reacts with oxygen is 258 kilocalories per gram-mole of zirconium. When zirconium reacts with fluorine to form zirconium tetrafluoride, the heat of reaction is 457 kilocalories per gram-mole, almost 80 percent more. The compounds of fluorine are handled more easily than the element and actually liberate more heat when reacted through the pure fluorine gas.[20]

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[19] Chemical Week. Rare Earths Step Out. V. 95, No. 20, Nov. 14, 1964, pp. 29–30.

A new chemical additive for gasoline, nickel alkyl phosphate, was prepared by Sinclair Oil Co. to cut preignition problems in engines due to deposit formation. Added in two to three parts per million, the organometallic phosphate does not boost the gasoline's octane rating as does tetraethyl lead, but it reportedly decreases rust and reduces ring wear.

Zirconium chemicals have been finding new applications which utilize unusual characteristics of the particular compound. A new floor wax which contains a zirconium complex that crosslinks carboxyl radicals on the polymer chain yields a durable finish to the wax which is resistant to detergents but at the same time readily reactable with ammonia to make the wax easily removable.

COATINGS

With aluminum and plastics being increasingly accepted by the canning industry, improvements in steel products are being sought. Tin-coated steel foil at 0.002-inch thickness became available during the year; U.S. Steel was first to announce the commercial availability of the material. The "thin tin" is less than a quarter of the thickness of traditional tinplate used for cans for fruits and vegetables and is twice as strong as aluminum foil of equal thickness. The weight of 100 square feet of the new tinned steel foil is 12 pounds, and the foil contains less than 4 ounces of tin. Production requires a high-speed mill specifically designed to cold-roll tinplate down to 0.001 inch thick and capable of rolling a 42-inch-wide strip at speeds up to 1,000 feet per minute.

Another development by U.S. Steel was a new process for coating light-gage, flat-rolled steel with aluminum or other metals. The new vapor-coating process was hailed as one of the major technological advances in the history of steelmaking. In the process, aluminum is heated in a crucible by an electron beam to a temperature in excess of 3,000° F at which the metal vaporizes readily. Then the vapor is deposited as a thin layer on a rapidly moving steel strip which passes through the condensing zone. A vacuum chamber is required to prevent the aluminum vapor from oxidizing. The high vacuum at which the electron beam furnace operates plus the steady, even heat source greatly facilitates the control of evaporation and subsequently the condensation of the aluminum metal. Construction of a continuous high-speed mill for producing the product was started at the Fairless Works plant in Fairless Hills, Pa. The aluminum coating can be made as thin as the tin coating applied to steel by the electrolytic tinning process, and the new product can be formed and drawn as easily as tinplate without damage to the coating.[21]

The combination of pure columbium or tantalum metals with zirconium diboride has led to an end product that appears capable of withstanding temperatures as high as 5,000° F for limited periods and 2,500° to 3,500° F for extended periods. In both instances, the zirconium diboride serves as a coating for the metals being applied by a plasma-spray technique. Although the two metals can withstand the high temperatures, they cannot withstand oxidizing conditions for long. Initial evaluation of three-eighths inch diameter columbium and tantalum tubing coated with a 0.010-inch-thick layer of diboride indicated the product could withstand fluorides encountered in molten aluminum and also in basic oxygen furnaces for steelmaking.[22]

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[20] Chemical & Engineering News. Flash Bulbs Brighter With Fluorine Filler. V. 42, No. 41, Oct. 12, 1964, p. 50.

[21] McManus, G. J. Will Aluminum Come to the Rescue of the Tinplate Producers? Iron Age, v. 194, No. 22, Nov. 26, 1964, pp. 23, 24.

PROCESSING

The current interest in dispersion-strengthened materials and fine-grain-sized metals has spurred researchers to develop new means of making ultrafine particles which can be fabricated as either pure metals or blended materials into products possessing improved properties and characteristics.

A freeze-drying technique developed by Bureau of Mines scientists was used successfully to prepare finely divided metal salts which subsequently were converted to submicron size metal powders. Tungsten and tungsten-rhenium metal powders, ranging in size from 40 to 500 angstroms, were obtained through the hydrogen reduction of ammonium tungstate either with or without the presence of ammonium perrhenate salts. The application of freeze drying in metallurgy depends essentially on the homogeneous properties of liquid solutions. If a solution containing a desired compound or compounds is frozen rapidly enough to prevent precipitation of the solute, and if there is no melting during sublimation of ice, the resulting dried material should theoretically retain the state of subdivision and degree of homogeneity of the original solution, thus yielding a minute crystal size. In the test studies, the starting solutions were rapidly frozen by pouring them into glass trays containing liquid nitrogen; the frozen solutions were quickly transferred to a commercial freeze-drying unit; and the water was removed by sublimation at pressures ranging from 50 to 100 microns. Reduction of the dried powder with hydrogen takes place between 250° and 700° C and requires 3 to 6 hours.

The Bureau investigated two other techniques for making fine metal powders. One method, involving the reaction of hydrogen with pure vaporized tungsten hexachloride, yielded tungsten powders of small-grain size and high purity. The resulting metal particles have an average diameter of about 0.03 micron. Analyses show average total metal impurities are less than 100 parts per million; carbon, nitrogen, and chlorine total 400 parts per million. Because of the very large surface area of the powder, the oxygen content is high, sometimes as much as 1.5 percent.

A second method, utilizing hydrogen reduction of tungsten trioxide, has been developed to produce a coarser powder but one which is purer than any previously reported in the literature. Impurity content of material consistently is less than 300 parts per million (both metallic and nonmetallic); as is usual with fine powders, oxygen is the main contaminant.

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[22] Chemical Week. Teamed to Tame Heat. V. 95, No. 16, Oct. 17, 1964, pp. 57–59.

The Air Force Materials Laboratory at Dayton, Ohio, announced it had developed a new double-duty process that would permit the production of submicron metal-oxide powder or the deposition of thin metal-oxide films. Although no industrial tests were carried out, the process is worth noting. In making powders, a liquid metal alkoxide, preferably the isopropoxide, is introduced into a primary vaporizer where it is heated to its boiling point. Preheated nitrogen is blown into this vaporizer to sweep the vapor and hot alkoxide liquid into a secondary vaporizer where the entrapped liquid is vaporized. The vapors pass next into a decomposition chamber where they are mixed with hot helium at 325° to 500° C, which causes the vapors to decompose into the metal oxide, olefin, and alcohol. The three reaction products then enter an electrostatic precipitator where the high-purity submicron oxide is collected. Alcohol and olefin are recovered from the effluent gas stream. Average size of the oxide particles is less than 100 angstroms. The process is altered slightly when a thin oxide film coating is desired. Graphite has been successfully coated with zirconia or hafnia by subjecting the heated graphite to a stream of hot alkoxide gas, constantly blown from the vaporizer into a deposition chamber in which the graphite body heated to 400° to 600° C resides. The gas decomposes to oxide upon contact with the hot substrate. Coatings 0.5 to 2 mils thick have been obtained in 30 to 180 minutes. Subsequent experiments have been designed to determine if powders and films can be made from mixed metal organics.[23]

The Supiro process for making pure tungsten powders was explained to be based upon the use of a pharmaceutical chemical, hexamine, as the reducing agent rather than hydrogen or carbon when producing metallic powder from tungsten oxide. This type of reduction, which can be performed below 400° C, can be carried out on other metal oxides of molybdenum, copper, nickel, iron, and cobalt to yield fine particles.

Zirconium and zirconium alloy powders have been made by a process developed by Penn Nuclear Corp., Penn, Pa. Metal powder with less than 1,200 parts per million oxygen was produced by the system, in which the equipment is entirely encapsulated in hermatically sealed helium-filled chambers. The starting metal, small ingot or heavy scrap turnings, dried in a vacuum oven, charged into a vacuum chamber where it is drawn up and accelerated by two counter-rotating, 10,000-revolution-per-minute turbine impellers and discharged into a two-directional, gas stream with a velocity of 550 revolutions per minute. Traveling in the two-directonal gas stream from opposite directions, the metal particles collide with such force that the resultant product is metal powder ranging in size from 80 to 400 mesh.

MHD Research Inc., Newport Beach, Calif., developed a process for preparing metal powders which involved the use of a plasma arc. The arc is struck between nonconsumable electrodes to vaporize the material to be powdered. Starting material, which can be either coarse powder or rod, is vaporized at 5,000° to 10,000° C in an inert gas atmosphere. The metal vapors are cooled, and the fine particles condense on collecting plates.[24]

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[23] Chemical Week. Double Feature Film Process. V. 95, No. 26, Dec. 26, 1964, p. 42.

[24] Chemical Week. Ultrafine Powder Push. V. 94, No. 10, Mar. 7, 1964, pp. 33, 34.

Vapor deposition of tungsten from tungsten hexafluoride has advanced to the point where one company was installing a 75,000-pound autoclave to produce high-purity tungsten shapes for use in rockets and other space applications. The new process yields a uniform, high-purity tungsten bead, which the autoclave pressure-bonds into various complex shapes in one step rather than the two steps required in powder metallurgy processes.

Another development in vapor deposition was a new accelerated electron beam gun developed by Materials Research Corp. of Orangeburg, N.Y. The gun, which has been designed to produce thin metallic and nonmetallic films in high vacuum, can achieve temperatures in excess of 3,600° C for controlled evaporating of such refractory materials as tungsten, tantalum, carbon, and metallic oxides. Under the work acceleration principle, a beam of electrons flows from an emitter (filament) to an anode (material). Upon striking the material to be deposited, the electrons release their kinetic energy, causing heating. The material holder is a water-cooled pedestal. Both pedestal and electron beam filaments are replaceable and can be supplied in various materials.

Several advances in continuous-casting techniques were announced during 1964.

A process for casting continuous sheets of lead was placed in operation in Australia. In the process, a rotating water-cooled drum is lowered about an eighth of an inch into a vat of molten lead which is maintained close to its melting point. The cooling action of the drum causes a thin layer of lead to solidify and adhere to the drum's surface. A blade peels the layer of lead off the drum as it rotates out of the melt, thus forming a continuous sheet of lead. The sheet passes directly through tension rollers and edge trimmers and is wound onto takeup reels. Casting speeds range from 30 to 100 feet per minute, depending on the thickness of the sheet being cast. About 70 feet per minute of 0.032-inch-thick sheet can be made.[25]

Continuous-casting techniques were extended to the production of copper rod. A new process was disclosed which involves the controlled flow of molten copper onto a revolving wheel. The copper rim of the wheel is grooved to receive the molten metal, which is retained in the groove by a steel belt. The moving metal is water-chilled into a continuous bar which leaves the wheel and passes through a rolling mill without interruption. Although a similar process had been applied to the making of aluminum rod, extensive metallurgical and mechanical development work was required before it could be successfully applied to process copper. Rolling rates exceed 10 tons per hour.[26]

Cerro Copper and Brass Co., Division of Cerro Corp., St. Louis, Mo., was installing a continuous-billet-casting installation with what is expected to be a record capacity of 30 tons per hour. The new installation comprises two Loma semicontinuous direct chill casting machines mounted in tandem and fed alternately from a holding furnace by a swinging launder system. The two machines will even produce six strands of 10- or 12-inch-diameter by 35-foot-long logs of phosphor deoxidized copper weighing as much as 45 tons. Liquid metal can be poured into one unit while the second is being readied for casting. Upon reaching the 35-foot level in the first unit, the liquid metal is allowed to flow into the second, and the cast logs are removed from the first machine. Since the first unit can be made ready for casting before the second is full of metal, the overall process is virtually one of uninterrupted continuous casting.[27]

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[25] Journal of Metals. Continuous Pb Sheet. V. 16, No. 2, February 1964, p. 146.

[26] Journal of Metals. Cu Rod Continuously Cast. V. 15, No. 12, December 1963, p. 882.

A continuous-casting machine of the curved-mold type is being installed by the Crucible Steel Company of America at the Midland, Pa., plant. This particular process involves the pouring of molten steel into a bottomless, water-cooled mold, where it solidifies and comes out in a continuous strand. Under controlled casting the strand is slowly carried through a gentle 90° bend by roller aprons, which guide and support the strand and simultaneously take up the ferrostatic pressure exerted by the liquid metal core upon the strand shell. Once horizontal, the strand passes through a roller leveler prior to being cut into the required lengths by a traveling slab cutoff torch. The Crucible facility will include two such units, each capable of producing strands up to 10 inches thick and 52 inches wide. Casting speed of up to 55 inches per minute per strand will permit a full 180-ton open-hearth heat to be cast in less than an hour.[28]

Bureau metallurgists at the Albany Metallurgy Research Center, Albany, Oreg., developed a method for making small castings of hafnium carbide which melts at about 7,000° F. The work was done in cooperation with AEC. The experimental casting apparatus consists of a water-cooled vacuum chamber enclosing a graphite ladle on a water-cooled base. An electrode, projecting into the chamber through the top, sends high voltage into the ladle to melt its contents. A mold is attached horizontally to the lip of the ladle, which is equipped with pivots. When the ladle is tipped downward, the molten material spills over its lip and into the mouth of the mold. A melting and pouring cycle can be completed in 3 to 4 minutes.

USE OF COMPUTERS

Computers are being adapted to pyrometallurgical and fabrication operations. Elaborate units now supervise rolling mills, calculate charges for basic oxygen converters, and perform complex integrations and differentiations. Practically all installations for making basic oxygen steel include computer facilities to aid in calculating the effects of production variables. A digital unit at 1 company can handle as many as 20 process variables for each heat. Data on such variables as hot metal charges, temperatures, and scrap and flux additions, along with the required steel composition are fed to the computer, which calculates the amount of oxygen that will produce the desired end point, thus allowing precise control. Sharon Steel Corp. was the first to apply computer methods for monitoring the melting process from charge to tap.[29]

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[27] Industrial Heating. Cerro Continuous Casting Plant to Deliver High Tonnage of Copper Billets. V. 31, No. 11, November 1964, p. 2205.

[28] Industrial Heating. Crucible Steel Installing Continuous Casting at Midland. V. 31, No. 12, December 1964, pp. 2398, 2400.

[29] Weymueller, C. R. Computers in Metalworking, Today and Tomorrow. Metal Prog., v. 85, No. 2, February 1964, pp. 109–113, 136.

The Wheeling Steel Corp. plant at Steubenville, Ohio, was installing a computer that would monitor the process variables of oxygen pressure and flow, hood temperatures, and lance cooling. In addition to the usual calculations of scrap and ore charge, oxygen-blowing rates, and quantities of additives, the computer will analyze and log data that will enable future application of a closed-loop control of the basic oxygen steelmaking process. Included in the improvement program of the Steubenville plant will be the construction of a computer-controlled hot strip mill and a 60-inch continuous-galvanizing line.

The first known application of a direct online computer control system for electric arc furnaces has been installed in a development program at Lukens Steel Co., Coatesville, Pa.

Foreign companies were indicating they, too, felt the computer offered vast improvements in the operation of production facilities. The Kawasaki Works of Nippon Kokan K.K., Japan, has an online computer control system for its blast furnace operations. Operating in two phases, the system reportedly controls the entire blast furnace operation, from raw material determinations to furnace adjustments. In the first phase of control, the computer determines the proper mixture of materials for the furnace burden. Also determined is the hot blast, including additions of steam, oxygen, and oil. The more advanced part of the control system is the second phase, which actually controls furnace conditions and makes rapid furnace adjustments. The development of controls for the steelmaking process was instrumental in working out the similar problems for the blast furnace control. The first successful test of control by computer in the blast furnace was made in November 1963.[30]

The computer has been the basis of control mechanisms of many of the recent space ventures. With improved materials of construction, the versatility of the computer grows. The structure for the Saturn V moon rocket's guidance computer is being fabricated from lithium-magnesium alloy. In addition to housing the computer electronics and memory, the metal serves as its own cold plate to carry off heat generated by the thousands of closely packed electronic components cooling the system about 18° F. The installed weight of the Saturn V computer was reduced approximately 65 pounds by the combination of lithium-magnesium and integral chassis cooling, compared with a conventional aluminum alloy chassis and separate cold plate. Next to beryllium metal, the alloy is believed to be the most efficient material for stiffness-to-weight but has none of the fabrication problems of beryllium. It has only half the density of aluminum and three-fourths that of magnesium, yet it has exceptional tensile strength and excellent thermal qualities for the space environment, and it minimizes the transmission of mechanical vibrations.

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[30] Journal of Metals. Blast Furnace Computer Control. V. 16, No. 4, April 1964, pp. 285, 286.

Review of Mining Technology

By Clarence O. Babcock [1] [2]

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ROCK BEHAVIOR has proved of national interest in a variety of fields. The behavior of rock consequent to a nuclear blast was used to detect such blasts, as criteria for the design of underground military defense installations that would resist nuclear blasts, and for judging the feasibility for peaceful uses of nuclear explosives. An obvious peaceful application of nuclear explosives would be for large-scale rock excavation, and plans were presented during the year to improve the present Panama Canal or create a new canal by this method. These plans were based largely on earlier crater tests that demonstrated rock behavior when subjected to a buried nuclear blast.

A knowledge of rock behavior under impact was used to evaluate the materials of the moon by means of the geometric configurations visible in the close-up pictures of the moon surface taken by the U.S. rocket Ranger 7. The composition of the moon must be considered in devising methods for taking samples of the surface layers or in designing underground shelters as bases for future explorations of the moon.

In more down-to-earth applications, an assessment was made of probable damage to surface buildings due to blasting, based on behavior of rock during such operations. The results of this work were considered by the State of Pennsylvania for revision of the State's safety code on blasting. The knowledge that has been developed on rock behavior found increased use in the design of underground mining and civil engineering operations. The public's concern for preservation of natural beauty added emphasis to the need for better knowledge of rock behavior as one aid in designing mining systems that will minimize subsidence and unsightly waste dumps.

Interest continued in the use of computer techniques, statistics, and operations research by the mining industry.[3] Data on rock properties and rock behavior are important input information for many uses of these techniques in mining. A report on progress in mining technology listed 240 items developed during the last 20 years.[4] Most of these advances were the result of improved equipment development and applied engineering, but an increasing number relied on knowledge of rock properties and behavior.

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[2] Compiled from material submitted by Bureau of Mines Mining Research Centers and Laboratories.

[3] Parks, George A. (ed.) Proc., 3d Ann. Conf. on Computers in the Mineral Industries, Stanford University, Palo Alto, Calif., June 24–29, 1963. Stanford Univ. Publ., Geol. Science, v. 9, No. 1–2, 1964.
Spear, Sherman W. (ed.) Proc. International Symposium on the Applications of Statistics, Operations Research, and Computers in the Mineral Industry, Golden, Colo., Apr. 20–24, 1964. Quarterly of the Colorado School of Mines, v. 59, No. 4, October, 1964, p. 1011.

EXPLORATION AND SAMPLING

Geologic factors which received increased attention included mineral and element associations, hydrothermal alteration, and isotope ratios and thermoluminescence of rocks in the vicinity of hydrothermal deposits.[5] Geochemical techniques continued to improve. Mercury appeared to be a promising trace element for locating sulfide ore deposits from the ground surface or from the air.[6] Tellurium appeared to be a usable trace element in gold telluride ore in the Cripple Creek, Colo., district.[7] Radioelements about southeastern Texas uranium deposits suggested that search spacing could be increased without decreasing the probability of detection.[8] Interest in optimal allocation of search effort by use of mathematical methods continued.

New developments in color photography and airborne infra-red sensors expanded the field of photogeology.[9] Photography was useful for structural analysis in semiarid areas, for rock identification, and for thermal mapping. Geothermal power was located by ground temperature measurements.[10]

New techniques and equipment were being developed to make measurements in the low-frequency portion of the electromagnetic spectrum; both natural (magnetotelluric) and induced electromagnetic field methods were studied. The induced polarization method had become a well-established technique in prospecting for sulfide ore and was one of the more important methods. Aeromagnetic surveying was still the most important reconnaissance technique, with respect to both extent of use and success in finding ore. Instrumentation, navigation techniques, and interpretation procedures were improved.[11]

The evaluation of mineral deposits by computer and statistical methods received attention. Sampling research by the Bureau of Mines developed statistical theory for use in evaluating mineral samples and deposits.[12]

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[7] Baxter, Robert A., and Stewart E. Poet. Geochemical Prospecting for Gold Telluride Ore. Mines Mag., v. 54, No. 9, September 1964, pp. 27–28.

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[9] Greenwood, J. E. G. W. Status and Development of Photogeology. Mining Mag., v. 110, No. 6, June 1964, pp. 382–399.

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[11] Redford, M. S., and J. S. Sumner. Aeromagnetics. Geophysics, v. 29, No. 4, August 1964, pp. 482–516.

[12] Becker, Robert M. Some Generalized Probability Distributions With Special Reference to the Mineral Industries (in Five Parts). 1. Sampling ton Items per Sample. BuMines Rept. of Inv. 6329, 1964, 53 pp.

Berkenkotter, R. D. Application of Statistical Analysis in Evaluating Bedded Deposits of Variable Thickness—Florida Phosphate Data. BuMines Rept. of Inv. 6526, 1964, 38 pp.

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DEVELOPMENT

Since 1955 when a number of 30-inch-diameter holes were drilled in the United States, thousands of feet of mine shafts up to 130 inches in diameter have been drilled. Shafts drilled in 1964 were used for mine operation, ventilation, access for excavation of underground storage facilities, utility conduits, bridge foundations, and missile silos. Materials drilled ranged in hardness from unconsolidated soil to rock as hard as granite. Multiple-pass and single-stage drilling methods were used. Most of the larger holes were by single stage, although in some a pilot hole was used for exploration, pressure grouting, or sealing fluid loss zones. Recommended methods included single pass to 12 feet in diameter and multiple pass over 12 feet, use of fluids in wet ground and air in dry ground for broken rock removal, and conventional circulation for holes less than 4 feet in diameter and reverse circulation for holes over 4 feet. Drilled shafts were competitive with conventionally drilled and blasted shafts, depending on hole diameter and hardness. In hard ground a 6-foot-diameter drilled shaft might be the largest competitive size, while a 25-foot-diameter drilled shaft might be competitive in very soft rock.[13] A record depth of 2,602 feet for a 72-inch-diameter rotary drill bit was reached in 6 months of contract drilling for the Nevada Operations Office of the Atomic Energy Commission at the Nevada test site. The shaft, which is to be 3,200 feet deep, is to provide facilities for underground nuclear testing.[14]

The M. A. Hanna's Homer-Wauseca iron ore mine used a 7-foot-diameter rotary drill to bore drifts at a 5-foot-per-hour rate at less than $15-per-foot direct cost. A 40-inch-diameter raise borer in use since 1962 completed fifteen 200-foot raises at less than $11 per foot. A goal of a 200-foot raise in 48 hours was set. Iron ore drilled ranged in compressive strength from 3,000 to 35,000 psi, and variations in hardness, not strength, increased drilling costs.[15]

American Gilsonite Company, Bonanza, Utah, used rotary drills to bore 54-inch drifts and 62-inch-diameter shafts in gilsonite.[16]

Bedded Deposits of the Phosphoria Formation in Idaho. BuMines Rept. of Inv. 6401, 1964, 29 pp.

Hazen, Scott W., Jr., and George W. Gladfelter. Using Unequal Sample Interval Lengths and Weighted Averages in Estimating Grade of Ore for Bedded Deposits. BuMines Rept. of Inv. 6406, 1964, 23 pp.

Hewlett, Richard F. Simulating Mineral Deposits Using Monte Carlo Techniques and Mathematical Models. BuMines Rept. of Inv. 6493, 1964, 27 pp.

Hewlett, Richard F. Application of Simulation in Evaluating Low-Grade Mineral Deposits. BuMines Rept. of Inv. 6501, 1964, 62 pp.

Hewlett, Richard F. Polynomial Surface Fitting Using Sample Data From an Underground Copper Deposit. BuMines Rept. of Inv. 6522, 1964, 27 pp.

Koch, George S., Jr., and Richard F. Link. Accuracy in Estimating Metal Content and Tonnage of an Ore Body From Diamond-Drill-Hole Data. BuMines Rept. of Inv. 6380, 1964, 24 pp.

Koch, George S., Jr., Richard F. Link, and Scott W. Hazen, Jr. Statistical Interpretation of Sample Assay Data From the Mi Vida Uranium Mine, Big Indian District, San Juan County, Utah. BuMines Rept. of Inv. 6550, 1964, 40 pp.

Link, Richard F., George S. Koch, Jr., and George W. Gladfelter. Computer Methods of Fitting Surfaces to Assay and Other Data by Regression Analysis. BuMines Rept. of Inv. 6508, 1964, 69 pp.

[13] Bromley, E. C., and J. W. Bawcom. Drilling Large Diameter Holes for Shafts. Min. Cong. J., v. 50, No. 8, August 1964, pp. 27–32.

[14] Mining Engineering. Deepest 72-in. Diameter Rotary Drilled Shaft Sunk for AEC by Loffland Bros. v. 16, No. 9, September 1964, pp. 68–69.

[15] Cannon, Robert E. Hard Rock Mole Teams Up With Raise Bores To Help Develop Homer-Wauseca Iron Mine. Eng. and Min. J., v. 165, No. 3, March 1964, pp. 86–89.

[16] Engineering and Mining Journal. Tunnel Borer and Shaft Drill Teamed at AGC's Hydraulic Mining Operations. V. 165, No. 7, July 1964, pp. 69–70.

Industry interest in mechanization of the raising process has produced raise climbers, birdcages, and rotary drills for this purpose since 1958 when the first raise climber was used in Sweden.[17]

DRILLING

The drilling industry was interested in both fundamental and practical aspects of rock drilling. A primary need continued to be a clear understanding of the rock characteristic-drilling process relationships. In particular, knowledge of rock failure mechanisms was needed to more efficiently apply energy under better control.[18]

Drillability studies continued in several countries. Results of research at the Postgraduate School in Mining of the University of Sheffield, England, suggested that a spring-loaded piston hammer, essentially a rebound hammer, gave test results that correlated with rock penetration tests with a single chisel cutting edge; it was also possible to infer the optimum energy input per inch of cutting edge length required for the drilling operation. The tests were limited to a few rock types.[19]

Bureau of Mines studies on rock drillability during the year included field drilling experiments in many rock types with both surface-set and impregnated-diamond bits, correlation of diamond drilling data and rock properties through computer analysis, and experimental investigation of static and dynamic force-penetration tests and strain wave measurements aimed at defining percussive tool drillability. Drillability predictions continued to be of interest in the oil industry, and many facets were presented in a series of articles in volume 62 of "The Oil and Gas Journal," in the issues of November and December 1964 (numbers 44–49).

Drilling innovations and equipment developments which received publicity included the horizontal drilling of large-diameter blastholes in surface mining,[20] single or multiple pass drilling with conventional or reverse circulation in large-diameter holes for use as development openings,[21] an elaborately controlled rotary-percussive drill jumbo capable of rates up to 6 feet per minute,[22] a successful turbodrill operation,[23] and overburden drilling in exploration through permafrost.[24] Other innovations included a percussive drill test device to measure drill torque, air consumption, and feed-leg piston pressure;

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Singh, Madan M. Rock Mechanics, Its Scope and Potential, Miner. Ind., College of Mineral Industries, Pennsylvania State University, v. 33, No. 5, February 1964, pp. 1–8.

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[21] Work cited in footnote 13.

[22] Engineering and Mining Journal. Indian Creek—The Prototype Project. V. 165, No. 4, April 1964, p. 89.

[23] Armstrong, Ted A. Turbodrill Cuts Hole Costs for Union. Oil and Gas J., v. 62, No. 29, July 20, 1964, pp. 50–51.

[24] Engineering and Mining Journal. Overburden Drilling Method Used in Permafrost Exploration. V. 165, No. 11, November 1964, p. 83.

use of shaped charges for drilling; and use of increased air pressure for down-the-hole hammers.[25]

Thirty-two oxygen-jet piercing drills were in operation in mines in Minnesota, Michigan, and Labrador. Further use of air-fuel gas burners, chiefly for chambering, was noted. This method was reported to cut drilling costs by as much as 50 percent in easily spallable rocks.[26] Increased use of drilled development openings, especially in rock of greater hardness, was largely due to the use of tungsten carbide inserts which were better able to withstand the large loading forces, impact, and abrasion.

A new Mohole turbodrill was expected to be easier to maintain and to remain on the bottom for longer drilling times than was the case for the earlier models. Computer-controlled equipment was designed to keep the Mohole drilling platform well within a 500-foot radius of the desired location in 18,000 feet of water.[27]

FRAGMENTATION

Studies on the uses of chemical and nuclear explosives for large-scale engineering projects were continued. Over the past 20 years, the U.S.S.R. has demonstrated the practicality of using large-scale conventional explosions for excavation, mining, and dam construction. If radioactive contamination can be controlled, the use of nuclear explosives for many engineering projects appears feasible, particularly excavation, roadway cuts, open pit mining, drainage diversion, and landslide removal or stabilization.[28] Excavation of a new sea-level canal by nuclear blasting was considered.[29] A U.S. Government report, Isthmian Canal Plans, 1960 (9 volumes), released in 1964, indicated that nuclear excavation of a sea-level canal was feasible and could be done for one-third the cost of converting the present Panama Canal to sea level by conventional means.

Strip mining of overburden from large low-grade copper or iron ore deposits seems feasible, based on the use of high-yield nuclear devices.[30] An experiment was performed using a 5.4-kiloton nuclear charge to demonstrate that nuclear explosives could be used to break large quantities of hard rock and that the broken rock could be mined by conventional techniques.[31] The use of nuclear explosives to facilitate petroleum and hydrocarbon recovery from underground deposits was suggested.[32]

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Austin, C. F. Use of Shaped Charges in Mining. Min. Cong. J., v. 50, No. 7, July 1964, pp. 56–61.

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[28] Circeo, Louis J., Jr. Engineering Properties and Applications of Nuclear Excavations. Univ. California Radiation Lab., UCRL–7657, February 1964, p. 46.

[29] Engineering News Record. A-Blasted Canal Seen as Ultimate Panama Solution. V. 172, No. 4, Jan. 23, 1964, pp. 38, 39.

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[30] Russell, Paul L. Stripping Overburden With Nuclear Explosives. Min. Eng., v. 16, No. 6, June 1964, pp. 76–80.

[31] Rabb, David D. Block Caving, Nuclear Style. Min. Eng., v. 16, No. 3, March 1964, pp. 48–52.

The use of ammonium nitrate-fuel oil (AN-FO) blasting agents continued to expand.[33] Approximately 70 percent of all production rock breaking in opencast and underground operations in the United States was done with AN-FO blasting agents.[34] International Nickel Co. reported that AN-FO blasting agents represented 94 percent of the total explosives used in the Sudbury mines.[35] The use of slurries is increasing at the expense of AN-FO, prills, and oil.[36] Aluminum slurry is claimed to produce better fragmentation, with wider spaced drill holes, than AN-FO.[37]

A study of the effects of blasting on mine roof bolts and rock in the upper shale production headings at the White Pine copper mine in Michigan indicates that the blasting caused roof bolt tension change and roof deterioration.[38] Studies of vibrations and mine damage due to underground blasting were continued at White Pine by the Bureau of Mines.

The size and shape of the strain pulse produced in rock by short cylindrical charges in drill holes were studied. Five explosives were compared for granite, and six, for limestone.[39] The size and shape of the strain pulse produced by explosives in rock were controlled primarily by the detonation pressure and the detonation impedance (product of explosive density and detonation velocity). The size and shape of the strain pulse in rock were significantly changed by the use of uncoupled charges. A simplified theory of decoupling agreed with later experimental results.[40] In general, decoupling had an adverse effect on the rock-breaking ability of explosives. Use of the cube root of charge weight as a scaling factor for predicting rock response to concentrated charges was satisfactory within the charge size range of 0.083 to 6 x 10^6 pounds.[41]

The fractures produced in rock models by blasting were different from the type produced in metals or plastics, and the use of these materials for the prediction of rock behavior was questioned.[42]

A new book summarized modern blasting technology as it had been built up in mining and civil engineering practice since 1945 through research, theoretical investigations, field tests, and full-scale applications.[43]

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[37] Grant, Charles H. Successful Aluminum Slurry Blasts Paved Way for Dow's 'Explosives Algebra.' Eng. and Min. J., v. 165, No. 8, August 1964, pp. 98–102.

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MATERIALS HANDLING: LOADING, TRANSPORTATION, AND HOISTING

One of the world's largest underground mines, the Swedish LKAB Company's iron ore mine in Kiruna, will be the first to install electronic data-processing equipment for the control and operation of a full-scale locomotive haulage system underground. The data-processing unit will be combined with a conventional central traffic control system for supervising the movements of 18 trains, each consisting of a 40-ton locomotive and 12 cars with a total capacity of 300 tons. The entire operation will be automatic, including the addressing of the trains to the loading and discharging stations. Information on the position of the trains, the level of filling in the shafts and pockets, train weights, and ore analyses will be automatically fed into the data center, which will be supervised by one man.[44]

A highly automated underground haulage system at the Gateway mine in Pennsylvania included closed-circuit television monitoring of a 1,300-ton-per-hour, 9.5-mile underground conveyor system believed to be the longest of its kind.[45] Television monitoring of a conveyor system was also used at the White Pine copper mine in Michigan.

A high-strength conveyor belt with a breaking strain in excess of 550 long tons was developed and installed in an English colliery. Coal is hauled from underground to the surface by a single-flight, rubber-covered, steel-cord belt 6,270 feet long.[46]

A new type of conveyor belting capable of carrying materials up 45-degree inclines now is being marketed by a British manufacturer. The belting has 1-inch-high rubber chevrons integrally moulded with the face cover.[47]

Total operating and maintenance cost was 2.0-cents-per-ton of ore hoisted by a television-monitored, 2,267-foot, 650-ton-per-hour conveyor on a 19-degree slope at the Gaspe Copper Mines, Ltd., Gaspe Peninsula, Canada.[48]

Uncrushed ore, with blocks to 2 tons in size, was handled at the Jeffrey mine, Canada, by a 30,000-ton-per-day, truck-skipway system from a depth of 400 feet.[49] Truck haulage cost to skipway was 8.2 cents per ton and skipway cost was 2.4 cents per ton while hoisting 8 million tons of ore. A truck-skipway cost of 10.6 cents and a 16-minute cycle compared favorably with a 15.5-cent-per-ton, 29-minute cycle for truck haulage alone.

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[44] Mining Journal Annual Review. Underground Mining—Haulage. June 1964, p. 115.

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[49] Fletcher, J. M. Jeffery Skipway-Operation and Maintenance. Canadian Min. and Met. Bull., v. 57, No. 628, August 1964, pp. 842–848.

GROUND SUPPORT AND CONTROL

New theories, concepts, and instruments were developed and new applications of rock mechanics to mine openings were tested and evaluated. These topics were the principal subjects of discussion at the Fourth International Conference on Strata Control and Rock Mechanics, the Sixth Symposium on Rock Mechanics, and the International Conference on the State of Stress in the Earth's Crust.[50] The influence of defects in rock, the geometric configuration of rock specimens, and the applied stress were evaluated in the determination of the mechanical and physical properties of rock, and coal measure rocks were found to be significantly influenced by composition, porosity and compaction.[51] Some of these results were reported by H. R. Hardy in a paper on "Concepts and Measurement of the Mechanical Properties of Rock," at the annual AIME national meeting.

Theories were developed to predict the influence of one mine opening upon another, the stress concentrations around shafts in complex stress fields, and the stress and the displacement around openings and pillars in evaporite minerals. Three of these theories were tested in full-scale underground mine operations and were found satisfactory for the prediction of deformation, strain, and stress around the mine openings and discussed in papers presented at the International Conferece on Strata Control and Rock Mechanics in May 1964.[52]

New instruments developed for laboratory and field measurements of deformation, strain, and stress included a biaxial borehole deformation gage, hydraulic pressure cells, and photoelastic stress meters.[53] Measured stresses in one study did not agree with inferred stresses, while in another study the stresses inferred from theory for flatjack and borehole deformation measurements were in agreement.[54] A new concept in model studies was used to predict the interaction of the stress in the rock and roof supports in gate roads and to duplicate the environment of a mine structure.[55]

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Rock mechanics programs at White Pine Copper Co., Michigan and Westvaco Mine, Wyoming were described by J. Bley and Wm. G. Fischer, respectively in papers presented at the annual AIME meeting in New York in February.

An apparatus and procedure for performing tests in a mine or tunnel to determine, in place, the modulus of rigidty of the rock was developed.[56] The modulus of rigidity is required in designing tunnel linings, other support structures, and in understanding elastic rock behavior.

A procedure was presented for the engineering design of a bolting system to reinforce a horizontally bedded roof, based primarily on the thickness of the rock layers and the anchorage capacity of the rock bolts.[57]

A technique was developed for estimating the creep rate in mine pillars, especially in salt, potash, and trona mines. The technique required the measurement of the creep rate in model pillars prepared from short lengths of exploration core.[58]

An apparatus was developed for measuring the static elastic constants of rock specimens subjected to triaxial confinement in the range of stress normally encountered in mining. Values so determined appeared to be more realistic for measuring in place behavior than those measured on unconfined specimens.[59]

The development and continual refinement of self-advancing hydraulic roof supports has resulted in an increased use in coal mines of automatic systems of longwall mining.[60] Many operations have reported fewer roof support problems with utilization of automated longwall systems. A metal mine in the United States reported the use of a longwall system incorporating steel friction props for immediate face support. In another metal mine a test area was mined using hydraulic props and a longwall system;[61] if the system proved workable, a support system with self-advancing hydraulic props was planned. Use of such systems in metal mines, including mines with steeply dipping veins, was expected.

The Bureau of Mines developed an explosively anchored rockbolt for which a patent (No. 3,148,577) was issued.[62] Tests in mines showed the bolt to be as effective as conventional bolts in hard rock and much more effective in soft rock, where conventional bolts failed at low load or could not be anchored at all. In very soft ground, the length of the explosively formed anchor tube could be varied up to the length of the hole itself, if necessary, to provide sufficient anchorage.

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[59] Obert, Leonard. Triaxial Method for Determining the Elastic Constants of Stress Relief Cores. BuMines Rept. of Inv. 6490, 1964, 22 pp.

[60] Campbell, L. C. Longwall Mining. A Breakthrough in United States Coal Production Technology. Min. Cong. J., v. 50, No. 8, August 1964, pp. 85–87.

[61] Huebner, G. R. White Pine Copper Looks at Longwalling. Min. Eng., v. 16, No. 12, December 1964, pp. 59–61.

Lipensky, M. Longwall Mining in Hardrock. Experience at San Francisco Manganese Ore Mine. Min. Eng., v. 16, No. 12, December 1964, pp. 53–56.

[62] Parsons, E. W., and Lars Osen. Field Testing of the Explosive-Anchored Rockbolt. BuMines Rept. of Inv: 6595, 1965, 40 pp.

Studies conducted in a Canadian mine with resin-anchored rockbolts, both tensioned and nontensioned, indicated that they may be used to advantage in certain mining situations.[63]

Studies of the support achieved when using mill tailings to fill underground openings and of methods of increasing the support capability of the tailings were conducted by the Bureau of Mines. Thorough investigation of the tailings fill used in four different mines showed that vibrating the fill material in place significantly increased its support capability.[64] Mines in Canada and the United States and the Federal Bureau of Mines investigated the increase in support that could be achieved by adding small amounts of cement to tailings fill.[65] Some Canadian mines had added the cement to their fill for better ground support as part of their routine mining cycle.

One coal mine conducted a large-scale test with sprayed rigid foam to reduce or eliminate sloughing in entryways caused by exposure to air and moisture.[66] Over 3,000 feet of entry had been sealed for the test.

DRAINAGE AND WATER CONTROL

A significant event in the field of drainage and water control was the passage by the 88th Congress and the signing into law by President Johnson of Senate bill 2. The act authorized funds to establish water resources institutes at land grant colleges or State universities in each State. The institutes were to support multipurpose water resource research centers. Additional funds were provided as dollar-for-dollar matching funds for specific water research projects. The impetus this will give to water resources research was expected to result in many advances in ground water engineering.

A cooperative study of acid mine drainage by the U.S. Department of the Interior and the U.S. Department of Health, Education, and Welfare was started. The Roaring Creek-Grassy Run watershed near Elkins, W. Va., was selected for a pilot study. The site, in the Monongahela River basin, was a logical choice because of the acidity of the water, area of watershed, number of abandoned mines above drainage, accessibility, and value of improved water quality for present and future utilization of the streams. The best presently known acid drainage control measures were to be applied, and the acid drainage problem, as found and altered by control, was to be assessed. The results were to be used to recommend solutions to similar problems on a nationwide scale.

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[63] McLean, D. C. Use of Resins in Mine Roof Support. Min. Eng., v. 16, No. 1, January 1964, pp. 36–40.

[64] Nicholson, David E., and William R. Wayment. Properties of Hydraulic Backfills and Preliminary Vibratory Compaction Tests. BuMines Rept. of Inv. 6477, 1964, 31 pp.

[65] Mameu, C. Mining Technology in 1963. Canadian Min. J., v. 85, No. 2, February 1964, pp. 135–151.

[66] Coal Age. Consol. Roof Control, Conditions—Methods—Research. V. 69, No. 10, October 1964, pp. 104–109.

Epoxy resins and quartz powder were used to seal a mine shaft.[67] Epoxy resin was also employed in a technique to keep sand out of oil wells.[68] The resin should also be useful in the treatment of mine drainage wells or in the solidification of difficult ground.

HEALTH AND SAFETY

The number of deaths in coal mining was a record low, and deaths per million man-hours worked were near a record low.

Performance of a rock drill muffler designed by electrical analogy circuits agreed with predicted results.[69] Muffler shape was not critical, and the muffler could be made a part of the drill shell. Increasing the number of exhaust openings for a given port area was the most effective way to reduce exit noise.[70]

Urethane foam was used to reduce spalling and sloughing of roof and rib, to erect fire-resistant powder magazines and transformer or compressor stations, to seal ventilation leaks, and to reduce heat transfer between mine rock and ventilation air.[71]

The numerical and analyser methods of solving ventilation problems were reviewed and compared.[72] A linear analyser used by the British National Coal Board proved to be the fastest of the methods tried.

Computer analysis of safety records indicated that safety statistics were best presented on an exposure basis.[73] The computer analysis of accident statistics brought out several points of possible significance: Accidents resulting in less than five fatalities occurred uniformly throughout the year, while major accidents resulting in more than five fatalities were more frequent during the winter, both fatal and nonfatal rates increased with increased production, an area in which a disaster occurred was the most likely candidate for the next disaster, and use of electronic data processing and retrieval of accident information on a national scale was desirable.

Methods for remote sealing of mine passageways through boreholes were investigated.[74] Methods included pneumatic injection of mineral wool and sand, ureaformaldehyde foam, balloons, and urethane foam, and caving by blasting.

MINING PRACTICE AND PERFORMANCE

Mining practices in bedded deposits, especially coal, for numerous countries were described at the Fourth International Conference on

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[67] Eberhard, A. U. Resin Sealing of Water-Bearing Beds in a Ruhr Shaft. Mining Mag., (London), v. 110, No. 3, March 1964, pp. 171–175.

[68] Robichaux, T. J., and D. A. Olivier. New Resin Keeps Sand Out of Well Bores. Oil and Gas J., v. 62, No. 45, November 9, 1964, pp. 218–221.

[69] DeWoody, R. T., J. W. Chester, and W. C. Miller. Noise From Pneumatic Rock Drills. Analogy Studies of Muffler Designs. BuMines Rept. of Inv. 6345, 1964, 24 pp.

[70] Chester, J. W., R. T. DeWoody, and W. C. Miller. Noise From Pneumatic Rock Drills. Shape and Exit Noise of an Exhaust Muffler. BuMines Rept. of Inv. 6450, 1964, 12 pp.

[71] Alston, George L. General Use of MSA Rigiseal Urethane Foam. Canadian Min. J., v. 85, No. 9, September 1964, pp. 76–77.

[72] Bray, J. W., and I. M. Plummer. Methods of Ventilation Analysis. Min. Mag., v. 110, No. 4, April 1964, pp. 224–237.

[73] Manula, Charles B., and Floyd J. Nelson. Evaluating Safety With Computers, Min. Cong. J., v. 50, No. 12, December 1964, pp. 55–59.

[74] Nagy, John, Donald W. Mitchell, and Edwin M. Murphy. Sealing a Coal-Mine Passageway Through a Borehole: A Progress Report. BuMines Rept. of Inv. 6453, 1964, 13 pp.

Strata Control and Rock Mechanics at Columbia University.[75] Presentation was timely because longwall mining was becoming, increasingly automated in Europe and interest for possible increased use of the method in the United States was growing rapidly. Facts and figures were presented in national reports.

In Australia older hardrock mining used rectangular timbered shafts, but newer shafts were circular or elliptical concrete lined with structural steel equipment. Normal stoping methods were flat back cut-and-fill, with or without square-set timber support and generally with recoverable vertical ore pillars. Deslimed mill tailings were placed hydraulically as stope fill. Mechanization of coal mining in Austria was expected to continue and to include cylindric-cutter (sic) loaders and ploughs. Steel arches replaced timber supports in roadways. In Belgium, mechanized coal face advance averaged 5.5 feet per day. Yielding arches and articulated arches on timber chocks allowed mining of otherwise unminable soft strata.

Stoping methods in Canadian metal and asbestos mines follow: Open stopes, 43 percent; filled stopes, 45 percent; and caved stopes, 12 percent. In shallow deposits, open and shrinkage stoping was still largely practiced, although cut-and-fill mining developed rapidly, particularly as mines deepened. A number of bedded deposits, such as iron in Newfoundland, salt in Nova Scotia and Ontario, and potash in Saskatchewan, were mined by machines developed for mechanized coal mining. In 1963, longwall mining produced 63 percent and room and pillar, 37 percent of 7.3 million tons of coal mined underground. Strip mining produced 3.2 million tons of coal. Rooms and pillars seldom exceeded 30 feet and 100 feet, respectively. Man-hours worked per ton mined decreased from 2.28 in 1952 to 1.26 in 1961 for metal, from 0.81 to 0.28 for industrial minerals, and from 2.36 to 1.76 for coal.

In coal mining the French were able to forecast the convergence, enabling selection of suitable support and so aiding roof control. Results of strength tests of rock from different mining districts were collected into a register in East Germany. The test conformed to standard methods of International Bureau for Rock Mechanics. In West Germany, the longwall method was used for all underground coal mining. In Great Britain, over 93 percent of deep-mined coal was produced from 2,600 coal faces of which 50 percent were mechanized and 50 percent nonmechanized. The average length of mechanized longwall face was 570 feet, and average advance was 5 feet per day. Nearly all seams worked were nearly level. Roofs were of shale, and floors were weak. Supports yielding at 20 to 25 tons provided adequate support. Nearly all coal mine faces were worked by longwall in the Netherlands. Coal could be worked by ploughs, and this equipment was preferred because of simple design and good performance. Both mining and tunneling were classed as hard-rock industries in Sweden.

Three articles on the economic and engineering design problems in open-pit mining included economic aspects of open-pit mining, technical and geological factors in slope stability, and techniques of slope and bench design.[76] Slope stability studies related to orientation of joints and faults offered hope for design of stable open-pit slopes.[77]

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[75] First work cited in footnote 50.

An arch-back stoping method, a variation of cut-and-fill was used to mine lead and zinc at the Cerro De Pasco mine in Peru.[78] Spontaneous combustion in large piles of broken ore, particularly if wet, prevented use of shrinkage or caving methods.

The largest nonnuclear mining blast in the United States was shot at the Climax Molybdenum Company's mine at Climax, Colo., when 208 tons of explosives broke almost 1.25 million tons of ore. Minor damage occurred to the mine; however, ore broken by the blast was under production within hours. Energy from the blast traveled 1,625 miles in 6 minutes, 37 seconds.[79]

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[76] Black, R. A. Economic and Engineering Design Problems in Open-Pit Mining. Mine and Quarry Eng., v. 30, No. 1, January 1964, pp. 13–15; No. 2, February 1964, pp. 66–74; No. 3, March 1964, pp. 112–120.

[77] Long, Albert E. Problems in Designing Stable Open-Pit Mine Slopes. Canadian Min. and Met. Bull., v. 57, No. 627, July 1964, pp. 741–746.

[78] Bemis, R. S., and H. A. Toelle. Arch-Back Stoping at the Cerro De Pasco Mine. Min. Cong. J., v. 50, No. 3, March 1964, pp. 31–33.

[79] Metal Mining and Processing. Anatomy of a Blast. V. 1, No. 8, August 1964, pp. 30–31.

Technologic Trends in the Mineral Industries (Metals and Nonmetals Except Fuels)

By F. L. Wideman[1]

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SPURRED by demands of a buoyant economy for mineral products, output from mines in the United States established a new record. Removal of waste material, necessary for the extraction of economic minerals, kept pace with mine production. Earth moving by these two activities exceeded 3 billion tons, an increase of 5 percent over that of 1963. Crude materials from which metal or nonmetal products were derived accounted for 75 percent of the total. The remainder, mostly worthless, was classified as waste.

Changes in the minerals industry result from many causes. Technological trends and labor productivity are among several significant and interrelated indexes that assist in the analysis of the changes. Therefore, a study of productivity is helpful in measuring technological growth in mining. Concepts of productivity tend to vary with the purpose for which the term is used; frequently, productivity is expressed in terms of units of output per unit of labor, such as tons of ore per man-hour or man-shift. Comparisons of levels of productivity for a group of products are usually made using composites of output. Data for all metal and nonmetal mines except gold, silver, mercury, platinum metals group, and sand and gravel were used to compile the composite for determining productivity for 1960–64. Copper ore, iron ore, and phosphate rock are mined mainly by surface methods, but characteristics of the deposits and differences in processing the crude material affect production of the commodities. Therefore, productivity data for these selected segments of the minerals industry reflect the influence of physical conditions on the exploitation of them.

Thirty years ago the approximate output per man-shift for the three commodities was as follows: Copper ore, 6 tons; iron ore, 10 tons; and phosphate rock, 5 tons.[2] The large increase in produc-

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[1] Commodity specialist, Division of Minerals.

[2] Haskell, A. P., Jr. and O. E. Kiessling. Technology, Employment, and Output Per Man in Phosphate-Rock Mining, 1880–1937. Works Project Administration. Rept. E–7, November 1938, 130 pp.

Leong, Y. S., Emil Erdreich, J. C. Buritt, O. E. Kiessling, C. E. Nighman, and G. C. Heikes. Technology, Employment, and Output Per Man in Copper Mining. Works Project Administration. Rept. E–12, February 1940, 260 pp.

Yaworski, N., O. E. Kiessling, C. H. Baxter, Lucien Eaton, and E. W. Davis. Technology, Emloyment, and Output Per Man in Iron Mining. Works Project Administration. Rept. E–13, June 1940, 264 pp.

TABLE 1.—Productivity of mines in the United States [1]

(Short tons per man-shift mining and processing) [2]

	1960	1961	1962	1963	1964
Metal mines:					
Ore produced	19.5	21.6	22.1	24.5	26.0
Total material handled	43.4	43.1	47.8	51.2	52.1
Nonmetal mines:					
Ore produced	22.3	23.6	24.0	23.9	24.4
Total material handled	28.1	28.6	30.1	31.0	31.6
All mines: [3]					
Ore produced	21.2	22.9	23.3	24.1	24.9
Total material handled	33.4	33.5	35.3	37.5	38.0
Copper mines:					
Ore produced	23.2	22.5	24.0	24.8	25.4
Total material handled	63.6	59.0	62.5	72.5	70.5
Iron ore mines:					
Ore produced	25.4	28.6	30.9	36.0	36.5
Total material handled	50.0	51.5	56.1	63.3	58.6
Phosphate rock mines:					
Ore produced	46.1	50.2	52.6	54.6	57.7
Total material handled	128.5	106.3	137.9	146.0	158.1

[1] Based on Bureau of Mines data for employment.
[2] Includes the first stage of processing only where possible.
[3] Excludes mines worked principally for gold, silver, mercury, and sand and gravel operations.

tivity resulted from many causes, among them a change from selective mining to mass production, an increase in mechanization, the use of larger and more efficient loading, hauling, and drilling equipment, the development of new techniques and explosives in blasting, and the rapid growth in recent years of automation in mining and processing.

The trend in open pit mining has been away from conventional methods and toward versatility.[3] Two decades ago, conventional churn drilling was used at almost all open pit mines. Since then jet piercing, tungsten carbide bits, rotary drilling, and many other improvements in drilling and blasting have been made. Loading and transportation methods changed to include a number of new machines and techniques. The trend in size of trucks was toward 85- to 200-ton capacities, but consideration was given to the advisability of engine horsepower being directed into speed and gradability rather than into units of greater capacity. Rail haulage was becoming fully automated and problems were simulated, analyzed, and revised by computers. Heavy equipment used in the construction industry found its way into huge earth moving projects in the mining industry.

Excavation is perhaps the most obvious and most practical application of nuclear energy to mining.[4] In a test a 100-kiloton thermonuclear device was placed 635 feet below the desert floor in alluvial fill. The crater resulting from the explosion had an apparent depth of about 325 feet and an average apparent diameter of about 1,200 feet. An estimated 7.5 million cubic yards of material was displaced.

Material Handled.—Output of ore and waste at metal and nonmetal mines in the United States in 1964 totaled 3,003 million tons, an increase of 5 percent over that of 1963. The quantity of materials handled has increased at an average annual rate of 6 percent since 1959. Ore production increased 6 percent over that of 1963, compared with an average rate of increase of 5 percent a year for the past 5 years. Waste removal in 1964 increased 1 percent over that of the previous year.

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[3] Engineering and Mining Journal. Versatility Key to Planning the Open-Pit. V. 165, No. 11, November 1964, pp. 81–111.

[4] Russell, P. L. Stripping Overburden With Nuclear Explosives. Min. Eng., V. 16, No. 6, pp. 76–79.

Crude ore production at metal mines increased 7 percent in 1964, which was comparable to the average annual rate of increase since 1959. Output of waste, however, decreased 2 percent from that of 1963, compared with an average increase of 6 percent annually since 1959. Ore and waste were each about half the material handled, compared with 48 percent and 52 percent, respectively, in 1963. Copper and iron ore accounted for 77 percent of the crude ore (74 percent in 1963) and 82 percent (80 percent in 1963) of the total materials handled. The Peter Mitchell mine of the Reserve Mining Co. supplanted Kennecott Copper Corp., Utah Copper Division, as the largest producer of ore in the United States. However, an enormous quantity of waste was stripped by Utah Copper Division, and the mine remained in first place in total materials handled.

Output of materials at nonmetal mines in 1964 totaled 2,083 million tons, an increase of 5 percent over that of 1963. Output of usable crude material increased 6 percent over that of the previous year, which is about the same as the average annual increase since 1959. The combined tonnage of material handled at sand and gravel pits and stone quarries was 81 percent of the nonmetal material handled.

Mines in six States—Arizona, Florida, California, Minnesota, Michigan, and Utah—again reported handling more than 100 million tons of materials. Arizona remained in first place with 285 million tons (261 million in 1963). Florida replaced California in second place by producing 251 million tons (234 million tons) compared with 248 million tons (243 million tons). Underground mines in the same five States as in 1963—New Mexico, Colorado, Arizona, Michigan, and Missouri—produced more than 10 million tons of material.

Average Value Per Ton of Principal Mineral Products and Byproducts.—The measurement of value used is the same as used throughout the Minerals Yearbook. Mine output is used in measuring value when possible. However, the value of the products from auxiliary processing is used for some minerals.

Value patterns remained essentially the same as in the last 3 years, with unit values for ore from underground mines generally larger than those of products from surface mining. The price of several mineral commodities increased during the year, whereas the price of others remained unchanged, and that of a few declined. The contribution of byproducts to the value of ore continued to be more significant to output of metal mines than to that of nonmetal mines.

A group of about 150 surface and underground metal mines was selected to test the feasibility of establishing a base to which physical and technological measurements can be related and trends projected.[5] Data used covered a 5-year period (1959–63), chosen because information was current and, more important, because the economy was the most stable and uniform of any similar period.

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[5] Allsman, Paul T. Developing a Program To Determine the Economic Value of Mineral Deposits With Respect to Time. Univ. of Arizona. Short Course and Symposium on Computers and Application of Computers to Mining and Exploration. V. 1, Sec. H, Mar. 15–19, 1965, 27 pp.

TABLE 2.—Material handled at surface and underground mines by commodities in 1964

(Thousand short tons)

Commodity	Surface			Underground			All mines		
	Crude ore	Waste	Total	Crude ore	Waste	Total	Crude ore	Waste	Total
Metals:									
Bauxite	1,949	877	2,826	260	--------	260	2,209	877	3,086
Beryllium concentrate	--------	--------	--------	--------	--------	--------	--------	--------	--------
Copper	134,579	279,553	414,132	24,333	330	24,663	158,912	279,883	438,795
Gold:									
Lode	418	7,096	7,514	2,330	1,276	3,606	2,748	8,372	11,120
Placer	28,271	3,992	32,263	27	9	36	28,298	4,001	32,299
Iron ore	175,270	115,901	291,171	19,604	1,698	21,302	194,874	117,599	312,473
Lead	3	107	110	6,136	695	6,831	6,139	802	6,941
Manganiferous ore	607	230	837	--------	--------	--------	607	230	837
Mercury	87	952	1,039	77	25	102	164	977	1,141
Molybdenum	--------	4,645	4,645	13,715	86	13,801	13,715	4,731	18,446
Nickel	1,813	471	2,284	--------	--------	--------	1,813	471	2,284
Silver	90	262	352	416	203	619	506	465	971
Titanium:									
Ilmenite	21,240	7,255	28,495	--------	--------	--------	21,240	7,255	28,495
Rutile	301	--------	301	--------	--------	--------	301	--------	301
Tungsten	--------	--------	--------	397	95	492	397	95	492
Uranium	2,585	29,418	32,003	3,614	1,038	4,652	6,199	30,456	36,655
Zinc	408	205	613	11,961	1,595	13,556	12,369	1,800	14,169
Other [1]	7,899	3,717	11,616	12	2	14	7,911	3,719	11,630
Total metals	375,520	454,681	830,201	82,882	7,052	89,934	458,402	461,733	920,135
Nonmetals:									
Abrasives [2]	158	59	217	36	--------	36	194	59	253
Asbestos	1,589	1,267	2,856	59	10	69	1,648	1,277	2,925
Barite	6,153	2,243	8,396	229	1	230	6,382	2,244	8,626
Boron minerals	1,754	6,431	8,185	2	--------	2	1,756	6,431	8,187
Clays	54,736	44,434	99,170	1,686	21	1,707	56,422	44,455	100,877
Feldspar	1,286	134	1,420	38	13	51	1,324	147	1,471
Fluorspar	96	86	182	413	18	431	509	104	613
Gypsum	8,163	9,532	17,695	2,555	--------	2,555	10,718	9,532	20,250
Mica	862	106	968	--------	19	19	862	125	987
Perlite	418	54	472	--------	--------	--------	418	54	472
Phosphate rock	73,362	130,166	203,528	1,497	79	1,576	74,859	130,245	205,104
Potassium salts	3	--------	3	17,358	803	18,161	17,361	803	18,164
Pumice	2,798	72	2,870	--------	--------	--------	2,798	72	2,870
Pyrites	--------	--------	--------	51	--------	51	51	--------	51
Salt	835	17	852	8,615	467	9,082	9,450	484	9,934
Sand and gravel	870,779	2,300	873,079	--------	--------	--------	870,779	2,300	873,079
Sodium carbonate (natural)	--------	--------	--------	1,680	--------	1,680	1,680	--------	1,680
Stone:									
Crushed and broken	695,408	65,367	760,775	34,009	373	34,382	729,417	65,740	795,157
Dimension	5,587	2,617	8,204	136	1	137	5,723	2,618	8,341
Sulfur:									
Frasch-process mines	7,148	--------	7,148	--------	--------	--------	7,148	--------	7,148
Other mines	1	--------	1	--------	--------	--------	1	--------	1
Talc, soapstone, and pyrophyllite	459	470	929	609	63	672	1,068	533	1,601
Vermiculite	988	3,388	4,376	--------	--------	--------	988	3,388	4,376
Other [3]	2,786	7,944	10,730	64	3	67	2,850	7,947	10,797
Total nonmetals	1,735,369	276,687	2,012,056	69,037	1,871	70,908	1,804,406	278,558	2,082,964
Grand total	2,110,889	731,368	2,842,257	151,919	8,923	160,842	2,262,808	740,291	3,003,099

[1] Antimony, beryllium, manganese, platinum-group metals, rare-earth metals and thorium, tin, vanadium, and zirconium.

[2] Emery, garnet, and tripoli.

[3] Aplite, diatomite, graphite, greensand marl, kyanite, lithium minerals, magnesite, olivine, sodium sulfate (natural), and wollastonite.

TABLE 3.—Material handled at surface and underground mines (including sand and gravel and stone), by States in 1964

(Thousand short tons)

State	Surface			Underground			All mines		
	Crude ore	Waste	Total	Crude ore	Waste	Total	Crude ore	Waste	Total
Alabama	30, 222	7, 021	37, 243	1, 522	163	1, 685	31, 744	7, 184	38, 928
Alaska	35, 177	2, 635	37, 812	2	3	5	35, 179	2, 638	37, 817
Arizona	98, 159	171, 431	269, 590	15, 044	376	15, 420	113, 203	171, 807	285, 010
Arkansas	34, 645	1, 691	36, 336	1, 340	--------	1, 340	35, 985	1, 691	37, 676
California	200, 427	45, 551	245, 978	1, 822	371	2, 193	202, 249	45, 922	248, 171
Colorado	27, 085	3, 527	30, 612	15, 469	634	16, 103	42, 554	4, 161	46, 715
Connecticut	16, 771	834	17, 605	--------	--------	--------	16, 771	834	17, 605
Florida	130, 586	120, 303	250, 889	--------	--------	--------	130, 586	120, 303	250, 889
Georgia	35, 299	22, 722	58, 021	1, 063	--------	1, 063	36, 362	22, 722	59, 084
Idaho	13, 837	11, 105	24, 942	1, 566	578	2, 144	15, 403	11, 683	27, 086
Illinois	78, 024	6, 253	84, 277	3, 158	3	3, 161	81, 182	6, 256	87, 438
Indiana	48, 147	3, 198	51, 345	1, 043	--------	1, 043	49, 190	3, 198	52, 388
Iowa	38, 322	8, 407	46, 729	2, 331	--------	2, 331	40, 653	8, 407	49, 060
Kansas	26, 623	638	27, 261	2, 644	19	2, 663	29, 267	657	29, 924
Kentucky	23, 839	2, 799	26, 638	5, 804	18	5, 822	29, 643	2, 817	32, 460
Louisiana	23, 058	--------	23, 058	2, 771	21	2, 792	25, 829	21	25, 850
Maine	15, 051	5	15, 056	8	--------	8	15, 059	5	15, 064
Maryland	29, 299	1, 155	30, 454	114	1	115	29, 413	1, 156	30, 569
Massachusetts	28, 123	68	28, 191	--------	--------	--------	28, 123	68	28, 191
Michigan	112, 812	12, 005	124, 817	14, 385	603	14, 988	127, 197	12, 608	139, 805
Minnesota	162, 891	67, 703	230, 594	1, 588	26	1, 614	164, 479	67, 729	232, 208
Mississippi	10, 711	1, 142	11, 853	--------	--------	--------	10, 711	1, 142	11, 853
Missouri	42, 834	4, 531	47, 365	14, 380	340	14, 720	57, 214	4, 871	62, 085
Montana	36, 968	3, 310	40, 278	3, 642	109	3, 751	40, 610	3, 419	44, 029
Nebraska	18, 568	5, 295	23, 863	--------	--------	--------	18, 568	5, 295	23, 863
Nevada	31, 875	47, 117	78, 992	205	65	270	32, 080	47, 182	79, 262
New Hampshire	9, 089	6	9, 095	--------	--------	--------	9, 089	6	9, 095
New Jersey	30, 883	2, 676	33, 559	908	3	911	31, 791	2, 679	34, 470
New Mexico	20, 440	22, 203	42, 643	19, 793	1, 213	21, 006	40, 233	23, 416	63, 649
New York	77, 880	8, 542	86, 422	6, 345	22	6, 367	84, 225	8, 564	92, 789
North Carolina	34, 215	3, 722	37, 937	73	--------	73	34, 288	3, 722	38, 010
North Dakota	10, 661	3, 419	14, 080	--------	--------	--------	10, 661	3, 419	14, 080
Ohio	78, 652	6, 996	85, 648	4, 527	200	4, 727	83, 179	7, 196	90, 375
Oklahoma	21, 716	1, 208	22, 924	1, 131	--------	1, 131	22, 847	1, 208	24, 055
Oregon	37, 626	787	38, 413	4	--------	4	37, 630	787	38, 417
Pennsylvania	70, 327	12, 947	83, 274	8, 243	1, 499	9, 742	78, 570	14, 446	93, 016
Rhode Island	2, 500	1	2, 501	--------	--------	--------	2, 500	1	2, 501
South Carolina	14, 309	3, 747	18, 056	--------	--------	--------	14, 309	3, 747	18, 056
South Dakota	16, 311	4, 664	20, 975	2, 057	1, 129	3, 186	18, 368	5, 793	24, 161
Tennessee	37, 758	4, 429	42, 187	6, 317	632	6, 949	44, 075	5, 061	49, 136
Texas	83, 529	2, 994	86, 523	283	--------	283	83, 812	2, 994	86, 806
Utah	42, 389	64, 821	107, 210	1, 660	432	2, 092	44, 049	65, 253	109, 302
Vermont	4, 951	912	5, 863	232	3	235	5, 183	915	6, 098
Virginia	41, 937	3, 221	45, 158	2, 867	31	2, 898	44, 804	3, 252	48, 056
Washington	43, 299	538	43, 837	994	50	1, 044	44, 293	588	44, 881
West Virginia	11, 363	1, 440	12, 803	2, 402	19	2, 421	13, 765	1, 459	15, 224
Wisconsin	48, 693	373	49, 066	1, 272	17	1, 289	49, 965	390	50, 355
Wyoming	15, 384	30, 717	46, 101	2, 910	343	3, 253	18, 294	31, 060	49, 354
Other States [1]	7, 624	559	8, 183	--------	--------	--------	7, 624	559	8, 183
Total	2, 110, 889	731, 368	2, 842, 257	151, 919	8, 923	160, 842	2, 262, 808	740, 291	3, 003, 099

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[1] Delaware, District of Columbia, and Hawaii.

TABLE 4.—Value of principal mineral products and byproducts of surface and underground ores mined in the United States in 1964

(Value per ton)

Ore	Surface			Underground			All mines		
	Principal mineral product	Byproducts	Total	Principal mineral product	Byproducts	Total	Principal mineral product	Byproducts	Total
Metals:									
Bauxite	$8.09	$0.12	$8.21	$8.16	-------	$8.16	$8.10	$0.11	$8.21
Copper	4.43	.76	5.19	6.80	$0.82	7.62	4.78	.77	5.55
Gold:									
Lode	5.58	.10	5.68	11.31	1.62	12.93	10.47	1.40	11.87
Placer	.16	-------	.16	.22	-------	.22	.16	-------	.16
Iron ore	3.93	-------	3.93	6.29	.18	6.47	4.17	.02	4.19
Lead	6.85	1.02	7.87	8.61	3.67	12.28	8.65	3.67	12.32
Manganese ore	28.29	.86	29.15	36.00	4.50	40.50	33.16	3.16	36.32
Manganiferous ore	3.80	-------	3.80	-------	-------	-------	3.80	-------	3.80
Mercury	29.46	-------	29.46	29.89	-------	29.89	29.68	-------	29.68
Molybdenum	-------	-------	-------	5.05	.10	5.15	5.05	.10	5.15
Nickel	3.54	-------	3.54	-------	-------	-------	3.54	-------	3.54
Platinum-group metals	.53	.01	.54	-------	-------	-------	.53	.01	.54
Silver	4.18	2.18	6.36	36.06	9.01	45.07	30.96	7.92	38.88
Titanium:									
Ilmenite	.87	.28	1.15	-------	-------	-------	.87	.28	1.15
Rutile	1.71	.13	1.84	-------	-------	-------	1.71	.13	1.84
Tungsten	-------	-------	-------	24.88	5.08	29.96	24.48	4.76	29.24
Uranium	21.72	.06	21.78	19.66	.27	19.93	20.53	.18	20.71
Zinc	19.71	7.66	27.37	11.05	2.98	14.03	11.34	3.14	14.48
Total	3.77	.30	4.07	8.19	1.14	9.33	4.57	.45	5.02
Nonmetals:									
Abrasive stone	57.75	11.25	69.00	-------	-------	-------	57.75	11.25	69.00
Asbestos	4.95	.01	4.96	5.46	-------	5.46	4.97	.01	4.98
Barite	1.49	.01	1.50	6.40	-------	6.40	1.66	.01	1.67
Clays	3.34	.01	3.35	7.47	-------	7.47	3.46	.01	3.47
Diatomite	42.17	-------	42.17	-------	-------	-------	42.17	-------	42.17
Emery	17.20	-------	17.20	-------	-------	-------	17.20	-------	17.20
Feldspar	4.22	.38	4.60	3.41	.05	3.46	4.20	.37	4.57
Fluorspar	27.41	7.28	34.69	14.16	3.91	18.07	16.08	4.40	20.48
Garnet	13.75	-------	13.75	-------	-------	-------	13.75	-------	13.75
Graphite	257.67	-------	257.67	-------	-------	-------	257.67	-------	257.67
Gypsum	3.43	-------	3.43	4.32	-------	4.32	3.64	-------	3.64
Kyanite	8.56	.16	8.72	-------	-------	-------	8.56	.16	8.72
Lithium minerals	6.27	.47	6.74	-------	-------	-------	6.27	.47	6.74
Magnesite	3.31	-------	3.31	-------	-------	-------	3.31	-------	3.31
Mica: Scrap	3.36	-------	3.36	-------	-------	-------	3.36	-------	3.36
Olivine	18.24	-------	18.24	-------	-------	-------	18.24	-------	18.24
Perlite	7.55	-------	7.55	-------	-------	-------	7.55	-------	7.55
Phosphate rock	2.09	-------	2.09	6.29	-------	6.29	2.17	-------	2.17
Potassium salts	-------	-------	-------	6.04	-------	6.04	6.04	-------	6.04
Pumice	2.31	-------	2.31	-------	-------	-------	2.31	-------	2.31
Pyrites	-------	-------	-------	4.51	-------	4.51	4.51	-------	4.51
Salt	3.29	.23	3.52	6.33	-------	6.33	6.06	.02	6.08
Sand and gravel	1.03	-------	1.03	-------	-------	-------	1.03	-------	1.03
Stone:									
Crushed and broken	1.40	-------	1.40	1.95	-------	1.95	1.43	-------	1.43
Dimension	17.17	.47	17.64	44.23	1.09	45.32	17.87	.49	18.36
Sulfur:									
Frasch	17.86	-------	17.86	-------	-------	-------	17.86	-------	17.86
Other	8.00	-------	8.00	-------	-------	-------	8.00	-------	8.00
Talc, soapstone, and pyrophyllite	5.33	-------	5.33	6.27	-------	6.27	5.87	-------	5.87
Tripoli	3.89	-------	3.89	4.42	-------	4.42	4.19	-------	4.19
Vermiculite	3.66	-------	3.66	-------	-------	-------	3.66	-------	3.66
Total	1.50	-------	1.50	4.69	.03	4.72	1.62	.01	1.63
Grand total	1.90	.06	1.96	6.60	.63	7.23	2.21	.10	2.31
Total nonmetals (excluding stone, sand and gravel)	3.95	.02	3.97	7.20	.05	7.25	4.52	.03	4.55
Total metals and nonmetals (excluding stone, sand and gravel)	3.82	.22	4.04	6.37	.80	7.17	4.56	.32	4.88

The mines were selected to give a wide range of diverse environmental characteristics and sizes. The technology of exploitation was fairly comprehensive and representative. Output of mines of copper, lead, zinc, and iron ore comprised the larger percentage of those selected, but production from several mines of other mineral commodities was added to obtain a wider variety of conditions. The data were prepared for surface and underground mines (table 5) and the latter category was subdivided according to stoping methods (table 6). The data were grouped on the basis of net value per ton of crude ore in ascending order.

Comparison of Production From Surface and Underground Mines.—Surface mining contributed 93 percent of the ore and 95 percent of the total material handled in 1964. Both percentages were virtually unchanged from 1963. However, a continuing increase in percentage of production by surface mining is indicated by a comparison with output in 1959, when 92 percent of the ore and 93 percent of the total

TABLE 5.—Summary of average annual crude ore and value of metal production at selected metal mines

Net value per ton	Number of mines	Average annual production of crude ore (thousand short tons)	Average annual production of material (thousand short tons)	Average annual value of production (thousands)	Net value per ton	Total material divided by crude ore	Average annual production per mine (thousand short tons)	Average annual value of production per mine (thousands)
Surface mines:								
$1.70–$2.50	3	5,218	7,168	$9,862	$1.89	1.37	1,739	$3,287
$2.50–$3.00	4	6,789	12,063	18,889	2.78	1.78	1,697	4,722
$3.00–$3.50	5	14,625	28,423	49,092	3.36	1.94	2,925	9,818
$3.50–$4.00	10	53,582	100,355	200,191	3.74	1.87	5,358	2,002
$4.00–$4.50	15	51,992	166,541	226,892	4.36	3.20	3,466	15,126
$4.50–$5.00	4	12,697	28,934	59,747	4.70	2.28	3,174	14,890
$5.00–$5.50	6	18,153	42,998	97,142	5.38	2.36	3,025	16,180
$5.50–$6.00	6	41,113	124,849	236,045	5.74	3.04	6,852	39,341
$6.00–$6.50	4	4,524	15,184	29,105	6.43	3.36	1,131	7,276
$6.50–$7.00	3	4,693	10,753	32,221	6.87	2.29	1,564	10,740
$7.00–$7.72	4	3,180	13,550	23,283	7.32	4.26	795	5,821
Total	64	216,566	550,818	982,469	4.54	2.54	3,384	15,351
Underground mines:								
$4–$5	3	17,351	----------	76,096	4.39	--------	5,784	25,365
$5–$6	5	18,669	----------	104,510	5.59	--------	3,733	20,902
$6–$7	12	3,858	----------	25,211	6.53	--------	321	2,101
$7–$8	10	4,979	----------	38,560	7.74	--------	498	3,856
$8–$9	14	6,353	----------	56,085	8.83	--------	454	4,006
$9–$11	8	4,386	----------	41,891	9.55	--------	548	5,236
$11–$13	6	4,207	----------	48,356	11.61	--------	701	8,143
$13–$18	5	453	----------	6,315	13.94	--------	91	1,263
$18–$23	5	1,173	----------	25,082	21.38	--------	235	5,016
$23–$32	5	2,120	----------	57,057	26.91	--------	424	11,411
$32–$39	6	1,614	----------	56,556	35.04	--------	269	9,426
$39–$47	5	479	----------	21,580	45.05	--------	96	4,316
Total	84	65,642	----------	557,299	8.49	--------	781	6,617
Grand total	148	282,208	----------	1,539,768	5.46	--------	1,907	10,407

TABLE 6.—Classification of selected underground metal mines by stoping method indicating correlation of grade of ore and physical characteristics of deposits

Stoping method	Physical character of deposits	Value per ton crude	Total annual production of crude ore (thousand short tons)	Number of mines	Average annual production per mine (thousand short tons)
Block caving	Very large and moderately stable—massive.	$4.88	24,535	3	8,178
Open stope—regular pillars	Large, regular, continuous, and stable—stratified.	5.47	13,459	9	1,495
Open stope—random pillars	Medium size, regular, discontinuous, stable—stratified.	7.35	2,651	7	379
Sublevel caving	Large, irregular, stable—masses	7.79	3,493	8	437
Panel caving	Large, irregular, continuous, moderate stability—masses.	8.97	5,122	6	854
Open stope—regular and random pillars.	Small, regular, discontinuous, stable—stratified.	9.21	959	9	106
Open stope-sublevel	Large, irregular, continuous, stable—masses.	9.38	4,672	7	667
Open stope—regular and random pillars.	Large, irregular, discontinuous, stable—masses.	14.15	3,764	9	418
Cut and fill	Large, irregular, continuous, unstable—veins and masses.	14.98	2,808	3	936
Open stope	Small, irregular, discontinuous, stable—masses.	16.91	285	4	71
Shrinkage	Wide, irregular, discontinuous, stable—veins.	17.02	669	2	334
Shrinkage	Narrow, irregular, discontinuous, stable—veins.	23.14	400	4	100
Square-set and other timbered stopes.	Large, irregular, discontinuous, very unstable—masses.	32.52	1,932	6	322
Cut and fill	Large, irregular, discontinuous, very unstable—veins.	39.42	894	7	128
Total		8.50	65,643	84	

material handled was produced by surface mining. Crude ore and waste handled at metal mines were 82 percent (82 percent in 1963) of the ore and 99 percent (98 percent in 1963) of the waste. In 1959, surface mines accounted for 79 percent of the ore and 96 percent of the waste produced at metal mines. Crude nonmetal material and waste from surface mines were 96 percent and 99 percent, respectively, of the total output of nonmetal mines, a relationship unchanged in the past 6 years.

Four commodities—molybdenum, tungsten, pyrite, and sodium carbonate (natural)—were mined by underground methods only. As in 1963, four ores—manganiferous nickel, ilmenite, and rutile—were mined entirely by surface methods. Nonmetals mined by surface methods included mica, perlite, pumice, sand and gravel, sulfur (other than Frasch-process), and vermiculite.

Underground mining continued to account for substantial percentages in four States—New Mexico, 49 percent (50 percent in 1963); Colorado, 36 percent (77 percent); Missouri, 25 percent (23 percent); and Kentucky, 20 percent (20 percent). Eleven States had no underground mines.

TABLE 7.—Crude ore and total material handled at surface and underground mines, by commodities in 1964

(Percent)

Commodity	Crude ore		Total material	
	Surface	Underground	Surface	Underground
Metals:				
Bauxite	88	12	92	8
Beryllium	100	---	100	---
Copper	84	16	94	6
Gold:				
Lode	15	85	68	32
Placer	100	---	100	---
Iron ore	90	10	93	7
Lead	---	100	---	100
Maganese ore	37	63	37	63
Manganiferous ore	100	---	100	---
Mercury	45	55	91	9
Molybdenum	---	100	25	75
Nickel	100	---	100	---
Rare-earth metals and thorium	100	---	100	---
Silver	14	86	36	64
Titanium concentrate:				
Ilmenite	100	---	100	---
Rutile	100	---	100	---
Uranium	33	67	87	13
Zinc	2	98	4	96
Total metals	81	19	90	10
Nonmetals:				
Abrasives:				
Emery	100	---	100	---
Garnet	100	---	100	---
Tripoli	43	57	97	3
Aplite	100	---	100	---
Asbestos	96	4	98	2
Barite	96	4	97	3
Boron minerals	100	---	100	---
Clays	97	3	98	2
Diatomite	100	---	100	---
Feldspar	97	3	97	3
Fluorspar	14	86	30	70
Graphite	100	---	100	---
Gypsum	76	24	87	13
Kyanite	100	---	100	---
Lithium minerals	100	---	100	---
Magnesite	100	---	100	---
Marl, greensand	100	---	100	---
Mica: Scrap	100	---	98	2
Olivine	100	---	100	---
Perlite	100	---	100	---
Phosphate rock	98	2	99	1
Potassium salts	---	100	---	100
Pumice	100	---	100	---
Pyrites	---	100	---	100
Salt	7	93	9	91
Sand and gravel	100	---	100	---
Sodium carbonate (natural)	---	100	---	100
Sodium sulfate (natural)	100	---	100	---
Stone:				
Crushed and broken	95	5	96	4
Dimension	98	2	98	2
Sulfur: Frasch-process mines	100	---	---	100
Talc, soapstone, and pyrophyllite	43	57	58	42
Vermiculite	100	---	100	---
Wollastonite	6	94	6	94
Total nonmetals	96	4	96	4
Grand total	93	7	95	5

TABLE 8.—Crude ore and total material handled at surface and underground mines, by States, in 1964

(Percent)

State	Crude ore		Total material	
	Surface	Underground	Surface	Underground
Alabama	95	5	96	4
Alaska	100	---	100	---
Arizona	87	13	95	5
Arkansas	96	4	96	4
California	99	1	99	1
Colorado	64	36	66	34
Connecticut	100	---	100	---
Delaware	100	---	100	---
District of Columbia	100	---	100	---
Florida	100	---	100	---
Georgia	97	3	98	2
Hawaii	100	---	100	---
Idaho	90	10	92	8
Illinois	96	4	96	4
Indiana	98	2	98	2
Iowa	94	6	95	5
Kansas	91	9	91	9
Kentucky	80	20	82	18
Louisiana	89	11	89	11
Maine	100	---	100	---
Maryland	100	---	100	---
Massachusetts	100	---	100	---
Michigan	88	12	89	11
Minnesota	99	1	99	1
Mississippi	100	---	100	---
Missouri	75	25	76	24
Montana	91	9	91	9
Nebraska	100	---	100	---
Nevada	99	1	100	---
New Hampshire	100	---	100	---
New Jersey	97	3	97	3
New Mexico	51	49	67	33
New York	92	8	93	7
North Carolina	100	---	100	---
North Dakota	100	---	100	---
Ohio	95	5	95	5
Oklahoma	95	5	95	5
Oregon	100	---	100	---
Pennsylvania	89	11	90	10
Rhode Island	100	---	100	---
South Carolina	100	---	100	---
South Dakota	89	11	87	13
Tennessee	86	14	86	14
Texas	100	---	100	---
Utah	96	4	98	2
Vermont	95	5	96	4
Virginia	94	6	94	6
Washington	98	2	98	2
West Virginia	83	17	84	16
Wisconsin	97	3	97	3
Wyoming	84	16	93	7
Total	93	7	95	5

Ratio of Ore to Marketable Product.—The ratio of ore to marketable product of most of the metals in 1964 was larger than that for 1963, indicating the continuation of declines in grade of ore. The average ratio for metals—ores of gold, mercury, platinum-group metals, and silver excepted—rose from 3.4:1 in 1959 to 3.9:1 in 1964. The ratio of crude nonmetal materials to marketable product remained virtually unchanged from that of 1963. The average ratio for nonmetals in 1964 was 1.1:1, unchanged from that of 1959.

Composites of units of marketable product and labor required for mining and the first processing of crude material have been used for comparing productivity. Between 1880 and 1917, when a period of expanding employment in the minerals industry ended, output per man-hour increased at the rate of 2.5 percent annually, whereas production increased at the annual rate of 5.9 percent.[6] There was a pronounced change in the trends between 1917 and 1929. The annual rate of productivity increased to 3.1 percent, whereas the rate increase of production was comparatively retarded. From 1929 to 1937, the downward trend of employment continued, and other factors influenced production and productivity. Although the minerals industry had recovered substantially by 1937 from a low point of production in 1932, production in 1937 was 91 percent of output in 1929 and man-hours worked were 73 percent.

From 1937 to 1959, production increased more than sixfold, while man-hours increased less than one-fifth. From 1959 to 1964, production of marketable products increased at the average annual rate of 3 percent. Conversely, employment declined slightly, resulting in an average annual increase in productivity of 3 percent.

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[6] Spencer, Vivian E. Production, Employment, and Productivity in Mineral Extractive Industries, 1880–1938. Works Project Administration Rept. S–2. June 1940, 168 pp.

TABLE 9.—Ore treated or sold per unit of marketable product at surface and underground mines in the United States by commodities in 1964

Commodity	Unit of marketable product	Surface			Underground			All mines		
		Ore (thousand short tons)	Marketable product, units	Ratio of units of ore to units of marketable product	Ore (thousand short tons)	Marketable product, units	Ratio of units of ore to units of marketable product	Ore (thousand short tons)	Marketable product, units	Ratio of units of ore to units of marketable product
Metals:										
Bauxite	Thousand long tons	1,948	1,404	1.4:1	260	197	1.3:1	2,208	1,601	1.4:1
Copper	Thousand short tons	131,467	892	147.3:1	23,113	241	95.9:1	154,580	1,133	136.4:1
Gold:										
Lode	Thousand troy ounces	403	64	6.3:1	2,334	755	3.1:1	2,737	819	3.3:1
Placer	Troy ounces	27,136	123,701	219.4:1	27	163	165.6:1	27,163	123,864	219.3:1
Iron ore	Thousand long tons	172,011	71,844	2.4:1	19,519	11,914	1.6:1	191,530	83,758	2.3:1
Lead	Thousand short tons	4	1	4.1:1	6,138	200	30.4:1	6,142	201	30.3:1
Mercury	Thousand flasks	74	7	10.9:1	76	7	10.5:1	150	14	10.7:1
Molybdenum	Thousand pounds	----------	----------	----------	13,715	46,378	.30:1	13,715	46,378	.30:1
Nickel	Thousand short tons	1,813	15	117.5:1	----------	----------	----------	1,813	15	117.5:1
Platinum-group metals	Thousand troy ounces	1,835	11	165.6:1	----------	----------	----------	1,835	11	165.6:1
Rare-earths and thorium concentrates.	Thousand short tons	2	2	1.0:1	----------	----------	----------	2	2	1.0:1
Silver	Thousand troy ounces	77	249	.31:1	404	11,269	.036:1	481	11,518	.042:1
Titanium: Ilmenite	Thousand short tons	21,130	965	21.9:1	----------	----------	----------	21,130	965	21.9:1
Uranium ore	do	2,400	2,668	.90:1	3,264	2,996	1.1:1	5,664	5,664	1.0:1
Zinc	do	407	30	13.8:1	11,834	482	24.6:1	12,241	512	24.0:1

Nonmetals:										
Aplite	Thousand long tons	165	121	1.4:1	--------	--------	--------	165	121	1.4:1
Asbestos	Thousand short tons	1,582	98	16.2:1	56	3	16.3:1	1,638	101	16.2:1
Barite	do	5,634	668	8.4:1	207	154	1.3:1	5,841	822	7.1:1
Boron minerals	do	1,754	584	3.0:1	1	1	1.2:1	1,755	585	3.0:1
Clays	do	53,725	50,187	1.1:1	1,688	1,685	1.0:1	55,413	51,872	1.1:1
Emery	do	10	9	1.0:1	--------	--------	--------	10	9	1.0:1
Feldspar	Thousand long tons	1,287	569	2.3:1	37	12	3.1:1	1,324	581	2.3:1
Fluorspar	Thousand short tons	75	62	1.2:1	445	122	3.6:1	520	184	2.8:1
Garnet	do	116	14	8.1:1	--------	--------	--------	116	14	8.1:1
Gypsum	do	8,120	8,128	1.0:1	2,556	2,556	1.0:1	10,676	10,684	1.0:1
Magnesite	do	629	629	1.0:1	--------	--------	--------	629	629	1.0:1
Mica: Scrap	do	858	91	9.4:1	--------	--------	--------	858	91	9.4:1
Perlite	do	407	350	1.2:1	--------	--------	--------	407	350	1.2:1
Phosphate rock	Thousand long tons	72,845	21,974	3.3:1	1,408	983	1.4:1	74,253	22,957	3.2:1
Potassium salts	Thousand short tons	--------	--------	--------	17,354	2,675	6.5:1	17,354	2,675	6.5:1
Pumice	do	2,788	2,777	1.0:1	--------	--------	--------	2,788	2,777	1.0:1
Pyrites	Thousand long tons	--------	--------	--------	51	46	1.1:1	51	46	1.1:1
Salt	Thousand short tons	835	511	1.6:1	8,272	8,271	1.0:1	9,107	8,782	1.0:1
Sand and gravel	do	870,779	870,779	1.0:1	--------	--------	--------	870,779	870,779	1.0:1
Sodium carbonate (natural)	do	--------	--------	--------	1,620	931	1.7:1	1,620	931	1.7:1
Stone:										
Crushed and broken	do	686,169	683,907	1.0:1	33,403	33,726	.99:1	719,572	717,633	1.0:1
Dimension	do	5,148	2,406	2.1:1	136	41	3.3:1	5,284	2,447	2.2:1
Sulfur:										
Frasch-process mines	Thousand long tons	6,562	5,859	1.1:1	--------	--------	--------	6,562	5,859	1.1:1
Other mines	do	1	1	1.1:1	--------	--------	--------	1	1	1.1:1
Talc, soapstone, and pyrophyllite	Thousand short tons	446	370	1.2:1	606	522	1.2:1	1,052	892	1.2:1
Tripoli	do	27	28	.98:1	36	36	1.0:1	64	64	1.0:1
Vermiculite	do	987	226	4.4:1	--------	--------	--------	987	226	4.4:1

TABLE 10.—Material handled per unit of marketable product at surface and underground mines in the United States, by commodities in 1964 [1]

Commodity	Unit of marketable product	Surface			Underground			All mines		
		Total material handled (thousand short tons)	Marketable product, units	Ratio of units of material handled to units of marketable product	Total material handled (thousand short tons)	Marketable product, units	Ratio of units of material handled to units of marketable product	Total material handled (thousand short tons)	Marketable product, units	Ratio of units of material handled to units of marketable product
Metals:										
Bauxite	Thousand long tons	2,825	1,404	2.0:1	260	197	1.3:1	3,085	1,601	1.9:1
Copper	Thousand short tons	410,965	892	460.5:1	23,414	241	97.1:1	434,379	1,133	383.2:1
Gold:										
Lode	Thousand troy ounces	5,262	64	81.8:1	3,578	755	4.7:1	8,840	819	10.8:1
Placer	Troy ounces	30,722	123,701	248.4:1	27	163	165.6:1	30,749	123,864	248.2:1
Iron ore	Thousand long tons	283,564	71,844	3.9:1	21,217	11,914	1.8:1	304,781	83,758	3.6:1
Lead	Thousand short tons	15	1	13.0:1	6,812	200	33.8:1	6,827	201	33.7:1
Mercury	Thousand flasks	1,026	7	148.7:1	103	7	14.1:1	1,129	14	79.8:1
Molybdenum	Thousand pounds	---	---	---	13,717	46,378	.30:1	13,717	46,378	.30:1
Nickel	Thousand short tons	2,268	15	147.0:1	---	---	---	2,268	15	147.0:1
Platinum-group metals	Thousand troy ounces	1,835	11	165.6:1	---	---	---	1,835	11	165.6:1
Rare-earths and thorium concentrates	Thousand short tons	2	2	1.0:1	---	---	---	2	2	1.0:1
Silver	Thousand troy ounces	335	249	1.3:1	520	11,269	.046:1	855	11,518	.074:1
Titanium: Ilmenite	Thousand short tons	28,385	965	29.4:1	---	---	---	28,385	965	29.4:1
Uranium ore	do	31,737	2,668	11.9:1	4,298	2,996	1.4:1	36,035	5,664	6.4:1
Zinc	do	612	30	20.7:1	13,394	482	27.9:1	14,006	512	27.4:1

Nonmetals:										
Aplite	Thousand long tons	174	121	1. 4:1	---	---	---	174	121	1. 4:1
Asbestos	Thousand short tons	2, 849	98	29. 2:1	66	3	19. 3:1	2, 915	101	28. 8:1
Barite	do	7, 876	668	11. 8:1	208	154	1. 3:1	8, 084	822	9. 8:1
Boron minerals	do	8, 184	584	14. 0:1	1	1	1. 7:1	8, 185	585	14. 0:1
Clays	do	98, 155	50, 187	2. 0:1	1, 711	1, 685	1. 0:1	99, 866	51, 872	1. 9:1
Emery	do	10	9	1. 1:1	---	---	---	10	9	1. 1:1
Feldspar	Thousand long tons	1, 420	569	2. 5:1	49	12	4. 1:1	1, 469	581	2. 5:1
Fluorspar	Thousand short tons	147	62	2. 4:1	463	122	3. 8:1	610	184	3. 3:1
Garnet	do	143	14	10. 0:1	---	---	---	143	14	10. 0:1
Gypsum	do	17, 652	8, 128	2. 2:1	2, 556	2, 556	1. 0:1	20, 208	10, 684	1. 9:1
Magnesite	do	1, 505	629	2. 4:1	---	---	---	1, 505	629	2. 4:1
Mica: Scrap	do	964	91	10. 6:1	---	---	---	964	91	10. 6:1
Perlite	do	461	350	1. 3:1	---	---	---	461	350	1. 3:1
Phosphate rock	Thousand long tons	203, 011	21, 974	9. 2:1	1, 487	983	1. 5:1	204, 498	22, 957	8. 9:1
Potassium salts	Thousand short tons	---	---	---	18, 112	2, 675	6. 8:1	18, 112	2, 675	6. 8:1
Pumice	do	2, 860	2, 777	1. 0:1	---	---	---	2, 860	2, 777	1. 0:1
Pyrites	Thousand long tons	---	---	---	51	46	1. 1:1	51	46	1. 1:1
Salt	Thousand short tons	852	511	1. 7:1	8, 739	8, 271	1. 1:1	9, 591	8, 782	1. 1:1
Sand and gravel	do	873, 079	870, 779	1. 0:1	---	---	---	873, 079	870, 779	1. 0:1
Sodium carbonate (natural)	do	---	---	---	1, 620	931	1. 7:1	1, 620	931	1. 7:1
Stone:										
Crushed and broken	do	749, 148	683, 907	1. 1:1	33, 774	33, 726	1. 0:1	782, 922	717, 633	1. 1:1
Dimension	do	7, 766	2, 406	3. 2:1	136	41	3. 3:1	7, 902	2, 447	3. 2:1
Sulfur:										
Frasch-process mines	Thousand long tons	6, 562	5, 859	1. 1:1	---	---	---	6, 562	5, 859	1. 1:1
Other mines	do	1	1	1. 1:1	---	---	---	1	1	1. 1:1
Talc, soapstone, and pyrophyllite	Thousand short tons	916	370	2. 5:1	663	522	1. 3:1	1, 579	892	1. 8:1
Tripoli	do	52	28	1. 9:1	36	36	1. 0:1	88	64	1. 4:1
Vermiculite	do	4, 376	226	19. 3:1	---	---	---	4, 376	226	19. 3:1

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[1] Based on ore treated or sold. Tonnages do not necessarily correspond to those in table 1.

Underground Methods.—Although the percentage of ore of certain commodities mined by underground methods changed in 1964 from 1963, the percentages for total output in the United States remained almost unchanged. Ore mined by open-stoping was approximately 75 percent of the total, and output from caving methods was about 24 percent. All bauxite, boron minerals, sodium carbonate, tripoli, and wollastonite mined underground came from naturally supported open stopes. Caving methods of mining were used to produce all the molybdenum ore mined in the United States, and half the copper and iron mined underground. Some mineral production was mined by underground methods in 39 States.

TABLE 11.—Mining methods used in underground operations by commodities

(Percent)

Commodity	Open stoping				Caving		Other and unspecified	
	Natural support		Artificial support					
	1963	1964	1963	1964	1963	1964	1963	1964
Metals:								
Bauxite	100.0	100.0	--------	--------	--------	--------	--------	--------
Copper	37.6	37.7	10.7	11.3	51.7	51.0	--------	--------
Gold: Lode	4.7	4.2	94.6	95.6	--------	.2	0.7	--------
Iron ore	47.9	44.6	2.4	8.4	49.2	45.2	.5	1.8
Lead	81.8	85.1	17.0	14.9	--------	--------	1.2	--------
Manganese ore	--------	--------	100.0	100.0	--------	--------	--------	--------
Mercury	1.6	2.7	80.7	82.6	17.7	14.7	--------	--------
Molybdenum	--------	--------	--------	--------	100.0	100.0	--------	--------
Silver	1.6	13.3	96.7	81.5	1.2	--------	.5	5.2
Uranium	67.1	67.8	31.2	27.4	1.7	4.8	--------	--------
Zinc	69.7	73.9	30.2	23.9	--------	2.2	.1	--------
Nonmetals:								
Asbestos	100.0	93.3	--------	--------	--------	6.7	--------	--------
Barite	--------	7.6	81.6	62.4	18.4	30.0	--------	--------
Boron minerals	100.0	100.0	--------	--------	--------	--------	--------	--------
Clays	91.9	94.0	7.4	5.6	.3	.4	.4	--------
Feldspar	28.2	36.8	71.8	63.2	--------	--------	--------	--------
Fluospar	39.8	35.1	54.5	58.1	5.7	6.8	--------	--------
Gypsum	99.5	99.3	.5	.7	--------	--------	--------	--------
Phosphate rock	28.0	29.3	69.1	67.5	2.9	3.2	--------	--------
Potassium salts	94.0	94.0	--------	--------	6.0	6.0	--------	--------
Pyrites	70.8	56.9	29.2	43.1	--------	--------	--------	--------
Salt	93.9	93.8	--------	--------	--------	--------	6.1	6.2
Sodium carbonate (natural)	100.0	100.0	--------	--------	--------	--------	--------	--------
Stone:								
Crushed and broken	98.2	98.1	.8	1.0	.3	--------	.7	.9
Dimension	94.6	94.1	--------	--------	5.4	5.9	--------	--------
Talc, soapstone, and pyrophyllite	57.8	65.6	16.6	15.9	3.6	1.3	22.0	17.2
Tripoli	100.0	100.0	--------	--------	--------	--------	--------	--------
Wollastonite	100.0	100.0	--------	--------	--------	--------	--------	--------
Total	65.9	65.8	8.7	9.1	24.7	24.2	.7	.9

TABLE 12.—Mining methods used in underground operations, by States

(Percent)

State	Open stoping				Caving		Other and unspecified	
	Natural support		Artificial support					
	1963	1964	1963	1964	1963	1964	1963	1964
Alabama	95.4	100.0			4.6			
Alaska	41.7		58.3	100.0				
Arizona	6.9	7.6	9.0	9.0	84.1	83.4		
Arkansas	85.9	86.5	11.3	8.5	2.8	5.0		
California	80.0	80.2	14.4	16.7	.3		5.3	3.1
Colorado	4.7	4.6	7.1	6.7	88.2	88.7		
Georgia	100.0	100.0						
Idaho	4.1	6.5	95.9	89.9		2.5		1.1
Illinois	94.4	95.3	4.9	4.0	.7	.7		
Indiana	100.0	100.0						
Iowa	100.0	100.0						
Kansas	100.0	100.0						
Kentucky	98.5	97.5	1.5	2.4		.1		
Louisiana	100.0	100.0						
Maine					100.0	100.0		
Maryland	100.0	100.0						
Michigan	76.5	77.5	4.2	4.2	18.7	15.8	.6	2.5
Minnesota	9.4	2.1			90.6	97.9		
Missouri	100.0	91.8		8.2				
Montana	15.4	17.5	84.5	82.5			.1	
Nevada	3.7	5.4	22.8	14.8	72.0	77.3	1.5	2.5
New Jersey	81.1	78.3	18.9	21.7				
New Mexico	88.7	90.4	6.0	4.0	5.3	5.6		
New York	89.1	90.2	.2		.2		10.5	9.8
North Carolina	12.6	11.0	87.4	78.0		11.0		
Ohio	99.7	99.6	.3	.4				
Oklahoma	100.0	100.0						
Oregon	100.0	50.0		50.0				
Pennsylvania	46.5	48.9	.6		52.9	51.1		
South Dakota	.2	1.2	99.7	98.8	.1			
Tennessee	100.0	100.0						
Texas	100.0	100.0						
Utah	32.6	34.6	58.2	57.4	5.7	8.0	3.5	
Vermont	82.7	88.4	9.4	11.6			7.9	
Virginia	92.7	89.9	.6	.6			6.7	9.5
Washington	91.3	90.8	7.3	8.7			1.4	.5
West Virginia	100.0	100.0						
Wisconsin	82.0	90.1			17.4	9.9	.6	
Wyoming	70.3	60.2	8.2	15.4	21.5	24.4		
Total	65.9	65.8	8.7	9.1	24.7	24.2	.7	.9

Surface Mining.—Practically all of the material handled at surface mines continued to be loaded mechanically. A large percentage of the ore in metal mining—lode gold, nickel, rutile, and uranium—required blasting. Multiple bench mines accounted for 86 percent of the output. Clays, diatomite, perlite, phosphate rock, sand and gravel, dimension stone, and sulfur were among the nonmetals mined with little or no blasting. Approximately 70 percent of the output of nonmetals came from open pit and single bench operations.

TABLE 13.—Mining methods used in open pit mining by commodities in 1964

(Percent)

Commodity	Mechanical loading		Other	Explanation of other
	Preceded by drilling and blasting	Not preceded by drilling and blasting		
Metals:				
Bauxite	94	6		
Beryllium			100	Hand methods.
Copper	96	4		
Gold:				
Lode	51	49		
Placer			100	Principally dredging.
Iron ore	83	17		
Manganese ore	100			
Manganiferous ore	100			
Mercury	81	17	2	Hand methods.
Nickel	5	95		
Platinum-group metals			100	Dredging.
Rare-earth metals and thorium	100			
Silver	97	3		
Titanium:				
Illmenite	100			
Rutile		100		
Uranium	33	67	1	
Zinc	100			
Nonmetals:				
Abrasive stone	75		25	Unspecified.
Aplite	35	65		
Asbestos	85	15		
Barite	7	93		
Boron minerals	97	3		
Clays	18	82		
Diatomite		100		
Emery	100			
Feldspar	60	34	6	Do.
Fluorspar	77	23		
Graphite	100			
Gypsum	82	16	2	Do.
Kyanite	100			
Lithium minerals	100			
Magnesite	98	2		
Marl, greensand		100		
Mica: Scrap	12	88		
Olivine	29	65		Hand methods.
Perlite	16	83		
Phosphate rock	1	99		
Pumice	1	99		
Sand and gravel		100		
Sodium sulfate (natural)		100		
Stone:				
Crushed and broken	94	6		
Dimension	28	2	70	Hand methods, drilled or cut without blasting.
Sulfur: Other than Frasch-process		100		
Talc, soapstone, and pyrophyllite	70	24	6	Hand methods, cut without blasting.
Vermiculite	62	38		
Total	47	51	1	

TABLE 14.—Kind of surface mining operation, by commodities, in 1964

(Percent of crude ore)

Commodity	Open pit	Single bench	Multiple bench
Metals:			
Bauxite	77	17	6
Copper	---	---	100
Gold: Lode	2	---	98
Iron ore	6	2	92
Manganiferous ore	90	10	---
Mercury	70	17	13
Nickel	---	---	100
Rare-earth metals and thorium	---	100	---
Tin	100	---	---
Titanium:			
Ilmenite	85	1	14
Rutile	18	---	82
Uranium	51	17	32
Zinc	---	---	100
Nonmetals:			
Abrasives:			
Emery	100	---	---
Garnet	---	---	100
Tripoli	100	---	---
Aplite	---	---	100
Asbestos	9	6	85
Barite	89	---	11
Boron	---	---	100
Clays	75	13	12
Diatomite	9	---	91
Feldspar	30	3	67
Fluorspar	18	---	82
Gypsum	59	12	29
Kyanite	---	56	44
Lithium ores	---	---	100
Magnesite	---	---	100
Marl, greensand	---	100	---
Mica: Scrap	100	---	---
Olivine	74	7	19
Perlite	39	38	23
Phosphate rock	84	13	3
Pumice	74	20	6
Sand and gravel	100	---	---
Stone:			
Crushed and broken	54	9	37
Dimension	41	14	45
Sulfur, other than Frasch	---	34	66
Talc, soapstone, and pyrophyllite	31	26	43
Vermiculite	2	---	98

TABLE 15.—Kind of surface mining operation by States in 1964

(Percent of crude ore)

State	Open pit	Single bench	Multiple bench
Alabama	82	5	13
Arizona	2	2	96
Arkansas	72	4	24
California	11	8	81
Colorado	29	23	48
Connecticut	47	38	15
Delaware	6	----------	94
District of Columbia	100	----------	----------
Florida	94	6	----------
Georgia	59	13	28
Hawaii	60	12	28
Idaho	20	1	79
Illinois	38	9	53
Indiana	41	14	45
Iowa	62	5	33
Kansas	93	3	4
Kentucky	67	10	23
Louisiana	100	----------	----------
Maine	98	----------	2
Maryland	44	7	49
Massachusetts	40	19	41
Michigan	43	3	54
Minnesota	3	2	95
Mississippi	79	5	16
Missouri	61	3	36
Montana	36	6	58
Nebraska	78	9	13
Nevada	4	----------	96
New Hampshire	85	5	10
New Jersey	56	3	41
New Mexico	7	4	89
New York	42	5	53
North Carolina	80	5	15
North Dakota	100	----------	----------
Ohio	70	8	22
Oklahoma	74	9	17
Oregon	33	9	58
Pennsylvania	49	11	40
Rhode Island	48	----------	52
South Carolina	78	----------	22
South Dakota	62	18	20
Tennessee	57	11	32
Texas	73	6	21
Utah	1	1	98
Vermont	38	2	60
Virginia	35	15	50
Washington	41	23	36
West Virginia	21	2	77
Wisconsin	53	9	38
Wyoming	33	3	64

Exploration and Development.—The downward trend in exploration and development was reversed in 1964 when 14.9 million feet, 9 percent more than that in 1963, was reported. For metals the total was 10.8 million feet, compared with 10.5 million in 1963, whereas footage for nonmetals increased from 3.2 million to 4.1 million. Decreased footage in raising and drifting more than offset increases in winze and shaft sinking, tunneling, and crosscutting. The decrease in total footage by underground excavation methods from 1963 was 8 percent compared with an average annual decrease of 6 percent in the last 5 years.

Exploration by drilling accounted for 13.0 million feet, an increase of 11 percent over 1963, and 87 percent of the total footage for exploration and development (85 percent in 1963). Approximately 72 percent of the drilling was for metals. In the last 5 years, exploration by drilling has decreased 5 percent. Footage from churn drilling, formerly an important method of exploration from the surface, dropped from 652,000 feet in 1960 to 266,000 feet in 1964, a decrease from 4 percent to 2 percent of the total footage drilled. The percentage of the total footage reported for diamond drilling was approximately the same in 1964 as in 1960. The footage for rotary drilling decreased from 35 percent to 32 percent, whereas footage by long-hole and percussion drilling increased from 32 percent to 35 percent and from 13 to 16 percent, respectively.

Output of ore and waste by exploration and development activities decreased 3 percent from that of 1963. Approximately 97 percent of the 456 million tons of material removed in 1964 was by stripping, compared with 98 percent in 1963. Material handled during the operations at metal mines dropped from 55 percent in 1963 to 46 percent in 1964. Tonnage produced by exploration and development of copper, iron, and uranium decreased. Output from lode gold and molybdenum increased sharply reflecting development of surface mines in Nevada and New Mexico. Exploration and development of clay, phosphate rock, and stone continued to contribute the greatest percentage of the quantity moved during exploration and development of nonmetals.

TABLE 16.—Exploration and development activity in the United States, by methods

Method	Metals		Nonmetals		Total	
	Feet	Percent of total	Feet	Percent of total	Feet	Percent of total
1963:						
Shaft and winze sinking	14, 445	0. 1	4, 858	0. 1	19, 303	0. 1
Raising	224, 163	2. 1	17, 344	. 5	241, 507	1. 8
Tunneling	38, 202	. 4	8, 834	. 2	47, 036	. 3
Drifting	759, 508	7. 2	82, 879	2. 6	842, 387	6. 2
Crosscutting	174, 931	1. 7	6, 409	. 2	181, 340	1. 3
Diamond drilling	1, 960, 927	18. 7	110, 385	3. 4	2, 071, 312	15. 2
Churn drilling	125, 311	1. 2	21, 942	. 6	147, 253	1. 1
Rotary drilling	1, 640, 919	15. 7	1, 848, 944	58. 8	3, 489, 863	25. 5
Long-hole drilling	1, 781, 107	17. 0	153, 003	4. 8	1, 934, 110	14. 2
Percussion drilling	3, 306, 267	31. 6	733, 941	23. 0	4, 040, 208	29. 6
Trenching	77, 999	. 7	10, 734	. 3	88, 733	. 6
Other	378, 220	3. 6	178, 130	5. 5	556, 350	4. 1
Total	10, 481, 999	100. 0	3, 177, 403	100. 0	13, 659, 402	100. 0
1964:						
Shaft and winze sinking	16, 860	. 2	12, 694	. 3	29, 554	. 2
Raising	202, 825	1. 9	21, 157	. 5	223, 982	1. 5
Tunneling	60, 023	. 6	19, 733	. 5	79, 756	. 5
Drifting	609, 961	5. 6	111, 808	2. 7	721, 769	4. 8
Crosscutting	169, 740	1. 6	8, 415	. 2	178, 155	1. 2
Diamond drilling	2, 288, 147	21. 2	178, 903	4. 4	2, 467, 050	16. 5
Churn drilling	243, 095	2. 2	23, 387	. 6	266, 482	1. 8
Rotary drilling	1, 949, 804	18. 0	2, 159, 625	52. 5	4, 109, 429	27. 5
Long-hole drilling	1, 805, 689	16. 7	308, 967	7. 5	2, 114, 656	14. 2
Percussion drilling	3, 026, 945	28. 0	1, 009, 693	24. 5	4, 036, 638	27. 1
Trenching	38, 318	. 3	2, 305	. 1	40, 623	. 3
Other	401, 704	3. 7	256, 890	6. 2	658, 594	4. 4
Total	10, 813, 111	100. 0	4, 113, 577	100. 0	14, 926, 688	100. 0

TABLE 17.—Exploration and development by methods and selected metals and nonmetals in 1964

(Feet)

	Shaft and winze sinking	Raising	Tunneling	Drifting	Crosscutting	Trenching	Diamond drilling	Churn drilling	Rotary drilling	Long-hole drilling	Percussion drilling	Other	Total
Metals:													
Copper	3,720	48,450	775	114,299	9,972	6,104	921,439	30,121	571,710	29,070	31,231	838	1,767,729
Gold	1,879	18,056	5,161	61,985	4,276	15,816	116,530	7,308	158,508	36,162	19,616	4,918	450,215
Iron ore	112	57,896	28,969	119,848	19,243	1,120	271,598	7,159	91,603	405,388	700,990	288,708	1,992,634
Lead	1,758	13,545	2,775	67,157	8,135	1,340	406,095	177,761	20,417	44,738	621,384	99,052	1,464,157
Mercury	270	791	140	4,374	26	150	1,400	---	10,322	17,445	---	40	34,958
Molybdenum	375	2,645	2,900	22,082	6,461	---	63,470	---	76,444	97,752	---	---	272,129
Silver	3,530	10,853	6,078	30,680	5,504	11,655	46,872	450	38,430	21,330	17,680	819	193,881
Tungsten	50	5,886	4,110	6,236	657	489	12,740	---	---	80	---	---	30,248
Uranium	2,279	14,917	8,000	111,214	110,932	1,076	192,368	2,091	931,068	1,121,979	576,111	1,426	3,073,461
Zinc	2,807	29,616	1,015	71,611	4,184	---	239,478	9,159	5,461	28,465	1,028,144	4,858	1,424,798
Other [1]	80	170	100	475	350	568	16,157	9,046	45,841	3,280	31,789	1,045	108,901
Total metals	16,860	202,825	60,023	609,961	169,740	38,318	2,288,147	243,095	1,949,804	1,805,689	3,026,945	401,704	10,813,111
Nonmetals:													
Asbestos	---	300	360	1,805	220	---	2,670	---	---	1,560	---	---	6,915
Barite	45	801	---	2,678	91	---	---	3,000	---	1,200	---	14,980	22,795
Boron minerals	---	20	---	373	---	---	1,699	---	11,176	---	---	---	13,268
Clays	210	5,000	2,060	10,333	250	150	14,325	---	732,893	---	360	16,893	782,474
Fluorspar	594	396	---	1,940	512	---	5,733	415	1,000	170	---	---	10,760
Gypsum	---	---	---	230	---	---	8,624	---	112,223	20	107,222	8,000	236,319
Phosphate rock	6,870	3,090	---	22,668	973	---	6,592	---	113,421	---	---	8,604	162,218
Potassium salts	2,800	192	3,586	3,075	712	---	24,883	---	175,367	---	---	---	210,615
Pumice	---	---	---	---	---	---	---	---	6,800	---	---	3,000	9,800
Sodium carbonate (natural)	---	---	---	43,200	---	---	---	---	---	---	---	---	43,200
Stone	200	6,621	1,750	17,446	1,772	1,845	107,074	15,472	727,548	305,817	901,061	203,925	2,290,531
Sulfur: Frasch	---	---	---	---	---	---	---	---	150,662	---	---	---	150,662
Talc, soapstone, and Pyrophyllite	1,975	4,573	2,750	4,408	1,585	50	5,100	---	400	---	---	232	21,073
Other [2]	---	164	9,227	3,652	2,300	260	2,203	4,500	128,135	200	1,050	1,256	152,947
Total nonmetals	12,694	21,157	19,733	111,808	8,415	2,305	178,903	23,387	2,159,625	308,967	1,009,693	256,890	4,113,577
Grand total	29,554	223,982	79,756	721,769	178,155	40,623	2,467,050	266,482	4,109,429	2,114,656	4,036,638	658,594	14,926,688

[1] Antimony, bauxite, beryllium, ilmenite, manganese ore, manganiferous ore nickel, platinum-group metals, and rare-earth metals and thorium.

[2] Abrasives, diatomite, feldspar, scrap mica, olivine, perlite, salt, vermiculite, and wollastonite.

TABLE 18.—Exploration and development by methods and States in 1964

(Feet)

State	Shaft and winze sinking	Raising	Tunneling	Drifting	Crosscutting	Trenching	Diamond drilling	Churn drilling	Rotary drilling	Long-hole drilling	Percussion drilling	Other	Total
Alabama							4,425	4,025	65,400			29,496	103,346
Alaska	24			20		171	3,600	6,003				70	9,888
Arizona	1,641	41,958	1,638	91,074	10,999	705	715,092	26,318	651,567	12,800	2,769	838	1,557,399
Arkansas		741		2,528	91		804		3,183				7,347
California	2,585	16,110	8,943	27,568	4,877	1,768	128,762	6,941	44,574	19,635	93,415	5,191	360,369
Colorado	2,628	11,951	12,278	73,064	5,161	11,848	243,886	579	281,647	177,447	151,506	3,000	974,995
Connecticut							2,000						2,000
Florida							2,748		230,788			5,840	239,376
Georgia							8,059	3,000	464,355		336,100		811,514
Idaho	1,896	13,123	3,098	38,226	8,049	235	81,717		66,802	18,306	1,545,571	2,763	1,779,786
Illinois	70	396	700	940	602		8,787	415	46,095	8,800	76,160	4,500	147,465
Indiana							878	27	35,711		301,905		338,521
Iowa							6,335	2,620	79,777		20,800	4,000	113,532
Kansas				850					45,000				45,850
Kentucky	524			1,000	300		1,878		152,100	60			155,862
Louisiana			8,837						138,624			1,256	148,717
Massachusetts								10,000					10,000
Michigan	567	30,081	19,219	73,138	7,189	120	99,509		88,895	51,637	103,000	1,500	474,855
Minnesota				498			102,367	3,067	37,285	1,400	120,179	246,369	511,165
Missouri		10,093		49,350	12,463		398,594	181,761	31,550	373,913	480,000	125,424	1,663,148
Montana	1,238	3,677	100	21,197	1,896	2,740	3,731		124,075	11,141	5,500	4,089	179,384
Nebraska									5,000				5,000
Nevada	712	675	2,092	4,101	2,252	13,285	39,905	199	197,913	28,530	91,000	603	381,267
New Jersey		3,772		3,799			1,076				28,550		37,197
New Mexico	5,028	14,640	2,461	55,908	101,663	7,141	183,768	1,715	315,314	901,777	417,374	630	2,007,419
New York	131	19,310	7,423	27,188	767		108,770		2,000	200	950	59,842	226,581
North Carolina			40	67			994		4,016				5,117
North Dakota									500				500
Ohio			250				3,000		1,850	40			5,140
Oklahoma									2,200			6,500	8,700
Oregon	60	160	221	620	26	150	300	6,878		13,370	14,650	12,695	49,130
Pennsylvania	112	15,766	3,687	24,868	1,484		30,613		42,426	280,017	1,277		400,250
South Carolina						60		2,100			30,026		32,186
South Dakota	467	11,343	113	50,972	2,599		85,152		101,478	4,217		45	256,386
Tennessee	1,445	7,481		44,772			67,176	770	41,741	19,707	97,928	2,881	283,901
Texas									122,137	1,200	17,222		140,559
Utah	9,224	11,514	5,076	44,784	2,609	300	58,219	950	183,672	64,956	52,986	26	434,316
Vermont	450	1,200	800	900	80		3,000						6,430
Virginia		4,847	100	12,330			45,994		1,632			140,160	205,063
Washington	156	3,479	1,325	9,889	1,153	2,100	14,573		100	27,650	1,050	80	61,555
Wisconsin		152	905	376			3,958	9,114	169,048	80	46,720		230,353
Wyoming	596	1,513	450	61,742	13,895		7,380		330,974	97,773		796	515,119
Total	29,554	223,982	79,756	721,769	178,155	40,623	2,467,050	266,482	4,109,429	2,114,656	4,036,638	658,594	14,926,688

TABLE 19.—Total material (ore and waste) produced by exploration and development in the United States by commodities in 1964

(Thousand short tons)

Commodity	Shaft and winze sinking	Raising	Tunneling	Drifting	Crosscutting	Trenching	Stripping	Other	Total
Metals:									
Bauxite	--------	--------	--------	--------	--------	--------	878	--------	878
Copper	28	127	3	624	31	11	54,268	2	55,094
Gold:									
Lode	10	84	23	210	9	16	7,087	2	7,441
Placer	(1)	3	(1)	5	1	93	3,771	--------	3,873
Iron ore	2	158	52	794	215	5	103,769	53	105,048
Lead	17	90	10	635	46	2	99	263	1,162
Mercury	1	4	(1)	21	(1)	(1)	452	1	479
Molybdenum	6	19	12	189	29	--------	4,645	--------	4,900
Silver	329	69	25	160	24	24	65	5	701
Tungsten	(1)	23	47	23	2	1	--------	--------	96
Uranium	11	51	37	550	332	8	24,757	(1)	25,746
Zinc	37	158	15	743	35	--------	182	55	1,225
Other [2]	1	1	(1)	1	5	11	5,152	26	5,197
Total metals	442	787	224	3,955	729	171	205,125	407	211,840
Nonmetals:									
Asbestos	--------	1	1	7	1	--------	269	--------	279
Barite	(1)	2	--------	57	(1)	--------	373	--------	432
Clays	5	5	11	9	3	(1)	33,745	--------	33,778
Diatomite	--------	--------	--------	--------	--------	--------	785	--------	785
Feldspar	--------	--------	2	10	7	--------	114	--------	133
Fluorspar	7	2	--------	15	5	--------	34	--------	63
Gypsum	--------	--------	--------	1	--------	--------	7,921	--------	7,922
Magnesite	--------	--------	--------	--------	--------	--------	1,063	--------	1,063
Phosphate rock	29	10	--------	122	3	--------	128,819	10	128,995
Potassium salts	32	1	34	29	6	--------	--------	--------	102
Pumice	--------	--------	--------	--------	--------	--------	29	--------	29
Sodium carbonate (natural)	--------	--------	--------	419	--------	--------	--------	--------	419
Stone	1	31	130	431	21	40	49,179	2,459	52,292
Talc, soapstone, and pyrophyllite	6	12	15	21	6	(1)	344	1	405
Vermiculite	--------	--------	--------	--------	--------	--------	3,389	--------	3,389
Other [3]	--------	1	641	3	--------	--------	2,644	370	3,659
Total nonmetals	80	65	834	1,124	52	41	228,708	2,840	233,745
Grand total	523	852	1,056	5,079	783	211	433,834	3,280	445,583

[1] Less than ½ unit. May not total because of rounding.
[2] Antimony, beryllium, manganese ore, manganiferous ore, rare-earth metals and thorium, and titanium.
[3] Boron minerals, kyanite, lithium, mica, olivine, perlite, salt, and wollastonite.

TABLE 20.—Total material (ore and waste) produced by exploration and development in the United States, by States, in 1964

(Thousand short tons)

State	Shaft and winze sinking	Raising	Tunneling	Drifting	Cross-cutting	Trenching	Stripping	Other	Total
Alabama							7,183		7,183
Alaska	(1)			(1)		1	2,518		2,519
Arizona	12	112	5	553	47	1	53,870	2	54,602
Arkansas		1		57	(1)		1,417		1,475
California	11	54	187	90	9	3	28,916	2	29,272
Colorado	22	58	54	364	14	109	278		899
Connecticut							275		275
Florida							120,381		120,381
Georgia							22,721		22,721
Idaho	22	107	15	228	45	3	9,738	15	10,173
Illinois	(1)	2	2	6	7		5,954		5,971
Indiana							3,168		3,168
Iowa							8,547		8,547
Kansas				1			498		499
Kentucky	6			9	3		2,799		2,817
Louisiana			640					370	1,010
Maine							5		5
Maryland							665		665
Michigan	3	58	25	414	39	3	12,031		12,573
Minnesota				1			67,476		67,477
Mississippi							588		588
Missouri		71		552	175		2,872	312	3,982
Montana	7	19	(1)	108	7	8	3,059	13	3,221
Nebraska							5,285		5,285
Nevada	3	2	9	19	11	28	8,724		8,796
New Jersey		67		139			169		375
New Mexico	48	45	11	320	316	13	5,535		6,288
New York	1	45	15	130	6		4,705	2,237	7,139
North Carolina			(1)	1			3,504		3,505
North Dakota							2,593		2,593
Ohio			1				4,571		4,572
Oklahoma							719		719
Oregon	(1)	1	1	1	(1)	(1)	185	26	214
Pennsylvania	2	30	21	238	22		3,707		4,020
South Carolina							3,747		3,747
South Dakota	3	40	(1)	151	8		3,686		3,888
Tennessee	28	18		541			4,429	44	5,060
Texas							2,136		2,136
Utah	350	81	40	264	11	38	1,474	1	2,259
Vermont	1	2	4	3	(1)		158	1	169
Virginia		16	2	312			1,583	179	2,092
Washington	1	18	8	48	16	4	606	(1)	701
West Virginia							1,003	43	1,046
Wisconsin		(1)	14	2			368		384
Wyoming	3	5	2	527	47		19,988	(1)	20,572
Total	523	852	1,056	5,079	783	211	433,834	3,245	445,583

[1] Less than ½ unit; may not total because of rounding.

Statistical Summary

By Kathleen J. D'Amico

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THIS SUMMARY appears in Minerals Yearbook volumes I and III, which cover mineral production in the United States, its island possessions, the Canal Zone, and the Commonwealth of Puerto Rico, as well as the principal minerals imported into and exported from the United States. The several commodity and area chapters contain further details on production. A summary table comparing world and U.S. mineral production also is included.

Mineral production may be measured at any of several stages of extraction and processing. The stage of measurement used in the chapter is normally what is termed "mine output." It usually refers to minerals in the form in which they are first extracted from the ground, but customarily includes for some minerals the product of auxiliary processing operations at or near mines.

Because of inadequacies in the statistics available, some series deviate from the foregoing definition. The quantities of gold, silver, copper, lead, zinc, and tin are recorded on a mine basis (as the recoverable content of ore sold or treated). The values assigned to these quantities, however, are based on the average selling price of refined metal, not the mine value. Mercury is measured as recovered metal and valued at the average New York price for metal.

The weight or volume units shown are those customary in the particular industries producing the respective commodities. No adjustment has been made in dollar values for changes in purchasing power of the dollar.

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[1] Statistical officer, Division of Minerals.

TABLE 1.—Value of mineral production in the United States,[1] by mineral groups [2]

(Millions)

Year	Mineral fuels	Nonmetals (except fuels)	Metals	Total	Year	Mineral fuels	Nonmetals (except fuels)	Metals	Total
1925	$2,910	$1,187	$715	$4,812	1945	$4,569	$888	$774	$6,231
1926	3,371	1,219	721	5,311	1946	5,090	1,243	729	7,062
1927	2,875	1,201	622	4,698	1947	7,188	1,338	1,084	9,610
1928	2,666	1,163	655	4,484	1948	9,502	1,552	1,219	12,273
1929	2,940	1,166	802	4,908	1949	7,920	1,559	1,101	10,580
1930	2,500	973	507	3,980	1950	8,689	1,822	1,351	11,862
1931	1,620	671	287	2,578	1951	9,779	2,079	1,671	13,529
1932	1,460	412	128	2,000	1952	9,616	2,163	1,617	13,396
1933	1,413	432	205	2,050	1953	10,257	2,350	1,811	14,418
1934	1,947	520	277	2,744	1954	9,919	2,733	1,518	14,170
1935	2,013	564	365	2,942	1955	10,780	3,076	2,055	15,911
1936	2,405	685	516	3,606	1956	11,741	3,391	2,358	17,490
1937	2,798	711	756	4,265	1957	12,709	3,387	2,137	18,233
1938	2,436	622	460	3,518	1958	11,589	3,466	1,594	16,649
1939	2,423	754	631	3,808	1959	11,950	3,861	1,570	17,381
1940	2,662	784	752	4,198	1960	12,142	3,868	2,022	18,032
1941	3,228	989	890	5,107	1961	12,357	3,946	1,927	18,230
1942	3,568	1,056	999	5,623	1962	12,784	4,117	1,937	18,838
1943	4,028	916	987	5,931	1963	r13,295	r4,318	r2,002	r19,615
1944	4,574	836	900	6,310	1964	13,585	4,622	2,265	20,472

r Revised.

[1] Excludes Alaska and Hawaii, 1925–53.

[2] Data for 1925–46 are not strictly comparable with those for subsequent years, since for earlier years value of heavy clay products has not been replaced by value of raw clays used for such products.

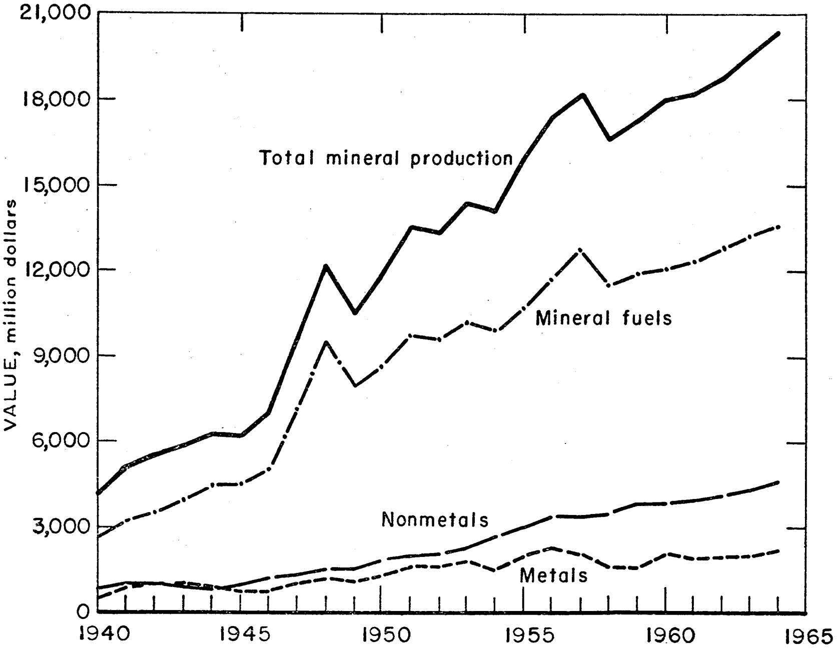

FIGURE 1.—Value of mineral production in the United States.

TABLE 2.—Mineral production [1] in the United States

Mineral	1961		1962		1963		1964	
	Quantity	Value (thousands)	Quantity	Value (thousands)	Quantity	Value (thousands)	Quantity	Value (thousands)
Mineral fuels:								
Asphalt and related bitumens (native): Bituminous limestone and sandstone and gilsonite....short tons..	1,558,792	$12,818	1,647,063	$14,601	1,632,645	$8,383	1,935,344	$10,038
Carbon dioxide, natural (estimate) thousand cubic feet..	545,354	82	1,144,107	146	1,295,545	178	1,236,816	166
Coal:								
Bituminous and lignite [2].....thousand short tons..	402,977	1,844,563	422,149	1,891,553	458,928	2,013,309	486,998	2,165,582
Pennsylvania anthracite....do....	17,446	140,338	16,894	134,094	18,267	153,503	17,184	148,648
Helium....thousand cubic feet..	551,785	10,263	599,519	20,905	627,344	21,957	667,440	23,360
Natural gas....million cubic feet..	13,254,025	1,996,241	13,876,622	2,145,301	14,746,663	2,328,030	15,546,592	2,387,689
Natural gas liquids:								
Natural gasoline and cycle products thousand gallons..	6,105,463	412,019	6,244,522	444,817	6,534,967	439,173	7,000,181	463,600
LP gases....do....	9,085,465	370,186	9,409,083	353,334	10,302,250	359,770	10,743,591	362,792
Peat....short tons..	531,067	5,036	566,441	5,186	546,621	5,423	639,365	6,181
Petroleum (crude)....thousand 42-gallon barrels..	2,621,758	7,565,582	2,676,189	7,774,051	2,752,723	7,965,743	2,786,822	8,017,078
Total mineral fuels....	XX	12,357,000	XX	12,784,000	XX	[r] 13,295,000	XX	13,585,000
Nonmetals (except fuels):								
Abrasive stone [3]....short tons..	2,495	238	2,653	260	2,693	255	3,186	292
Aplite....long tons..	97,465	651	125,156	912	(4)	(4)	(4)	(4)
Asbestos....short tons..	52,814	4,347	53,190	4,677	[r] 66,396	[r] 5,108	101,092	8,143
Barite....do....	697,804	9,300	860,312	9,820	823,615	[r] 9,402	829,741	9,796
Boron minerals....do....	602,613	46,936	646,613	49,336	700,183	54,981	776,000	60,871
Bromine....thousand pounds..	180,798	44,517	190,747	46,617	203,333	48,558	286,813	65,316
Calcite (optical grade)....pounds..	----	----	----	----	----	----	4	2
Cement:								
Portland....thousand 376-pound barrels..	314,821	1,048,832	325,476	1,070,371	342,036	1,095,884	374,230	1,145,108
Masonry....thousand 280-pound barrels..	19,275	55,737	19,998	57,405	20,997	59,599	22,397	63,305
Natural and slag....thousand 376-pound barrels..	269	968	402	1,611	352	1,407	283	1,057
Clays....thousand short tons..	47,389	156,829	47,797	163,012	[r] 50,135	[r] 180,810	52,853	192,537
Emery....short tons..	6,180	106	4,316	71	6,732	119	9,214	172
Feldspar....long tons..	496,808	5,120	492,476	5,076	548,954	5,525	629,894	6,132
Fluorspar....short tons..	197,354	8,940	206,026	9,166	[r] 199,948	[r] 9,001	217,137	9,723
Garnet (abrasive)....do....	12,057	1,036	14,166	1,172	14,626	1,412	16,123	1,622
Gem stones (estimate)....	(5)	1,309	(5)	1,296	(5)	1,421	(5)	1,474
Gypsum....thousand short tons..	9,500	34,996	9,969	36,343	10,388	38,138	10,684	38,874
Lime....do....	13,249	177,463	13,752	186,754	14,521	199,389	16,089	223,167
Magnesium compounds from sea water and brine (except for metals) short tons, MgO equivalent....	356,384	25,545	408,129	28,742	[r] 520,699	[r] 39,323	599,698	42,177

See footnotes at end of table.

TABLE 2.—Mineral production [1] in the United States—Continued

Mineral	1961		1962		1963		1964	
	Quantity	Value (thousands)	Quantity	Value (thousands)	Quantity	Value (thousands)	Quantity	Value (thousands)
Nonmetals—Continued								
Mica:								
Scrap short tons	99,044	$2,417	107,702	$2,639	109,323	$2,776	114,729	$3,353
Sheet pounds	526,007	3,386	363,016	1,299	102,961	13	242,662	58
Perlite short tons	310,338	2,664	320,330	2,663	325,132	2,727	349,867	3,073
Phosphate rock thousand long tons	18,559	130,535	19,382	134,304	19,855	139,861	22,960	161,067
Potassium salts thousand short tons, K_2O equivalent	2,732	104,464	2,452	94,859	^{r} 2,864	^{r} 110,164	2,897	114,100
Pumice thousand short tons	2,463	6,799	2,271	6,301	2,618	6,578	2,776	6,443
Pyrites thousand long tons	988	7,418	916	6,809	825	5,698	847	5,471
Salt thousand short tons	25,707	160,223	28,807	174,841	^{r} 30,641	^{r} 184,589	31,623	200,706
Sand and gravel do	751,784	751,301	776,701	794,725	^{r} 821,850	^{r} 847,272	868,779	894,092
Sodium carbonate (natural) short tons	805,828	20,444	977,584	24,330	1,119,081	27,616	1,274,745	30,451
Sodium sulfate (natural) do	465,814	9,296	457,881	9,092	435,257	8,392	575,033	10,989
Stone [6] thousand short tons	611,938	947,359	656,954	1,025,697	688,366	1,068,108	725,269	1,134,335
Sulfur:								
Frasch process mines thousand long tons	5,082	117,884	4,917	107,069	4,995	99,014	5,859	117,228
Other mines long tons	177,549	1,694	150,550	1,439	1,371	15	794	8
Talc, soapstone, and pyrophyllite short tons	762,380	5,277	771,728	5,278	804,358	5,505	889,949	6,218
Tripoli do	54,641	225	61,732	244	66,635	266	64,613	268
Vermiculite thousand short tons	206	3,350	205	3,293	226	3,572	226	3,613
Value of items that cannot be disclosed: Calcium-magnesium chloride, diatomite, epsom salts from epsomite (1961–63), graphite, iodine, kyanite, lithium minerals, magnesite, greensand marl, olivine, staurolite, wollastonite, and values indicated by footnote 4	XX	^{r} 47,993	XX	^{r} 49,436	XX	^{r} 54,929	XX	60,392
Total nonmetals	XX	3,946,000	XX	4,117,000	XX	4,318,000	XX	4,622,000
Metals:								
Antimony ore and concentrate short tons, antimony content	689	(7)	631	(7)	645	(7)	632	(7)
Bauxite long tons, dried equivalent	1,228,032	13,937	1,369,007	15,609	1,524,700	17,234	1,600,722	17,875
Beryllium concentrate short tons, gross weight	[8] 1,122	(7)	[8] 978	(7)	[8] 751	(7)	(7)	(7)
Chromite do	[9] 82,000	[9] 2,939	------	------	------	------	------	------
Copper (recoverable content of ores, etc.) short tons	1,165,155	699,093	1,228,421	756,707	1,213,166	747,310	1,246,780	812,901
Gold (recoverable content of ores, etc.) troy ounces	1,548,270	54,189	1,542,511	53,990	1,454,010	50,889	1,456,308	50,971
Iron ore, usable (excluding byproduct iron sinter) thousand long tons, gross weight	72,378	650,501	69,969	618,242	73,563	678,177	84,300	802,331
Lead (recoverable content of ores, etc.) short tons	261,921	53,956	236,956	43,602	253,369	54,727	286,010	74,935
Manganese ore (35 percent or more Mn) short tons, gross weight	46,088	3,224	24,758	(7)	10,622	(7)	26,058	(7)
Manganiferous ore (5 to 35 percent Mn) do	225,004	1,480	338,501	(7)	543,125	(7)	238,776	(7)
Mercury 76-pound flasks	31,662	6,257	26,277	5,024	^{r} 19,117	^{r} 3,623	14,142	4,452

Molybdenum (content of concentrate) thousand pounds	66,753	87,925	50,506	69,390	65,839	91,096	65,097	97,121
Nickel (content of ore and concentrate) short tons	13,133	(7)	13,110	(7)	13,394	(7)	15,420	(7)
Silver (recoverable content of ores, etc.) thousand troy ounces	34,794	32,166	36,798	39,929	35,243	45,076	36,334	46,980
Titanium concentrate:								
Ilmenite short tons, gross weight	782,629	13,320	809,037	13,974	890,071	16,529	1,003,997	19,178
Rutile do	7,664	778	8,033	933	11,311	1,262	10,547	1,016
Tungsten ore and concentrate short tons, 60 percent WO_3 basis	8,245	10,565	8,429	11,639	5,657	7,202	9,244	11,251
Uranium ore short tons	8,041,329	148,299	7,052,870	138,294	[r] 5,645,921	[r] 115,821	5,666,252	116,297
Vanadium (recoverable in ore and concentrate) do	5,343	19,076	5,211	18,605	[10] 3,862	[10] 13,788	4,362	13,061
Zinc (recoverable content of ores, etc.) do	464,390	106,848	505,491	116,413	529,254	122,533	574,858	156,308
Value of items that cannot be disclosed: Chromite,[9] cobalt, magnesium chloride for magnesium metal, manganiferous residuum, platinum-group metals (crude), rare-earth metal concentrates, tin, zirconium concentrate, and values indicated by footnote [7]	XX	22,582	XX	35,071	XX	36,827	XX	40,357
Total metals	XX	1,927,000	XX	1,937,000	XX	[r] 2,002,000	XX	2,265,000
Grand total mineral production	XX	18,230,000	XX	18,838,000	XX	[r] 19,615,000	XX	20,472,000

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[r] Revised. XX Not applicable.

[1] Production as measured by mine shipments, sales, or marketable production (including consumption by producers).

[2] Includes small quantity of anthracite mined in States other than Pennylsvania.

[3] Grindstones, pulpstones, millstones (weight not recorded), grinding pebbles, sharpening stones, and tube-mill liners.

[4] Figure withheld to avoid disclosing individual company confidential data; value included with "Nonmetal items that cannot be disclosed."

[5] Weight not recorded.

[6] Excludes abrasive stone, bituminous limestone, bituminous sandstone, and ground soapstone, all included elsewhere in table.

[7] Figure withheld to avoid disclosing individual company confidential data; value included with "Metal items that cannot be disclosed."

[8] Includes low-grade beryllium ore as follows: 805 tons in 1961, 760 tons in 1962, and 750 tons in 1963.

[9] Excludes quantity consumed by American Chrome Co.

[10] Final figure; superseded figure given in commodity chapter.

TABLE 3.—Minerals produced in the United States and principal producing States in 1964

Mineral	Principal producing States in order of quantity	Other producing States
Antimony	Idaho, Nev., Alaska	
Aplite	Va	
Asbestos	Calif., Vt., Ariz., N.C	
Asphalt	Tex., Utah, Ala., Mo	
Barite	Mo., Ark., Nev., Ga	Calif., Idaho., Ky., Mont., N. Mex., S.C., Tenn., Tex.
Bauxite	Ark., Ala., Ga	
Beryllium	S. Dak	Colo., Wyo.
Boron	Calif	
Bromine	Mich., Tex., Ark., Calif	
Calcium-magnesium chloride.	Mich., Calif., W. Va	
Carbon dioxide	N. Mex., Colo., Utah, Calif	Wash.
Cement	Calif., Pa., Tex., Mich	Ala., Ariz., Ark., Colo., Fla., Ga., Hawaii, Idaho, Ill., Ind., Iowa, Kans., Ky., La., Maine, Md., Minn., Miss., Mo., Mont., Nebr., N. Mex., N.Y., N.C., Ohio, Okla., Oreg., S.C., S. Dak., Tenn., Utah, Va., Wash., W. Va., Wisc., Wyo.
Clays	Ohio, Ga., Tex., Calif	All other States except Alaska and R.I.
Coal	W. Va., Pa., Ky., Ill	Ala., Alaska, Ark., Colo., Ga., Ind., Iowa, Kans., Md., Mo., Mont., N. Mex., N. Dak., Ohio, Okla., S. Dak., Tenn., Utah, Va., Wash., Wyo.
Cobalt	Pa	
Copper	Ariz., Utah, Mont., N. Mex	Alaska, Calif., Colo., Idaho, Mich., Mo., Nev., Oreg., Pa., Tenn., Wash., Wyo.
Diatomite	Calif., Nev., Wash., Ariz	Oreg.
Emery	N.Y	
Feldspar	N.C., Calif., Conn., Ga	Ariz., Colo., Maine, N.H., S.C., S. Dak., Va.
Fluorspar	Ill., Ky., Mont., Nev	Colo., N. Mex., Utah.
Garnet, abrasive	N.Y., Idaho	
Gold	S. Dak., Utah, Ariz., Wash	Alaska, Calif., Colo., Idaho, Mont., Nev., N. Mex., Oreg., Pa., Tenn., Wyo.
Graphite	Tex	
Gypsum	Calif., Mich., Iowa, Tex	Ariz., Ark., Colo., Ind., Kans., La., Mont., Nev., N. Mex., N.Y., Ohio, Okla., S. Dak., Utah, Va., Wyo.
Helium	Tex., Okla., N. Mex., Kans	
Iodine	Mich., Calif	
Iron ore	Minn., Mich., Calif., N.Y	Ala., Ariz., Ark., Colo., Ga., Idaho, Mo., Mont., Nev., N.J., N. Mex., Pa., Tex., Utah, Va., Wisc., Wyo.
Kyanite	Va., S.C., Ga	
Lead	Mo., Idaho., Utah, Colo	Ariz., Calif., Ill., Kans., Ky., Mont., Nev., N. Mex., N.Y., Okla., Oreg., Va., Wash., Wis.
Lime	Ohio, Pa., Mich., Tex	Ala., Ariz., Ark., Calif., Colo., Conn., Fla., Hawaii, Idaho, Ill., Iowa. La., Md., Mass., Minn., Miss., Mo., Mont., Nebr., Nev., N.J., N. Mex., N.Y., Okla., Oreg., S. Dak., Tenn., Utah, Vt., Va., Wash., W. Va., Wis., Wyo.
Lithium	N.C., Calif., S. Dak	
Magnesite	Nev., Wash	
Magnesium chloride	Tex	
Magnesium compounds	Mich., Calif., Tex., N.J	Fla., Miss.
Manganese ore	Mont., N. Mex	
Manganiferous ore	Minn., N. Mex., Mont	
Marl	N.J. ,Md	

TABLE 3.—Minerals produced in the United States and principal producing States in 1964—Continued

Mineral	Principal producing States in order of quantity	Other producing States
Mercury	Calif., Nev., Alaska, Ariz.	Idaho, Oreg.
Mica:		
Scrap	N.C., Ga., Ala., S.C.	Ariz., Calif., Conn., Idaho, N. Mex., Pa., S. Dak.
Sheet	N.C.	
Molybdenum	Colo., Utah, Ariz., N. Mex.	Calif., Nev., N. Dak., S. Dak.
Natural gas	Tex., La., Okla., N. Mex.	Ala., Alaska, Ariz., Ark., Calif., Colo., Fla., Ill., Ind., Kans., Ky., Md., Mich., Miss., Mo., Mont., Nebr., N.Y., N. Dak., Ohio, Pa., Tenn., Utah, Va., W. Va., Wyo.
Natural gas liquids	Tex., La., Okla., N. Mex.	Ark., Calif., Colo., Fla., Ill., Kans., Ky., Mich., Miss., Mont., Nebr., N. Dak., Pa., Utah, W. Va., Wyo.
Nickel	Oreg.	
Olivine	Wash., N.C.	
Peat	Mich., Ind., Pa., Wash.	Alaska, Calif., Colo., Conn., Fla., Ga., Idaho, Ill., Iowa, Maine, Md., Mass., Minn., Mont., Nev., N.J., N.Y., N. Dak., Ohio, S.C., Vt., Wis.
Perlite	N. Mex., Ariz., Nev., Calif.	Colo., Idaho, Oreg., Tex., Utah.
Petroleum	Tex., La., Calif., Okla.	Ala., Alaska, Ariz., Ark., Colo., Fla., Ill., Ind., Kans., Ky., Mich., Miss., Mo., Mont., Nebr., Nev., N. Mex., N.Y., N. Dak., Ohio, Pa., S. Dak., Tenn., Utah, Va., W. Va., Wyo.
Phosphate rock	Fla., Tenn., Idaho, Mont.	Ark., N.C., Utah, Wyo.
Platinum-group metals	Alaska, Calif.	
Potassium salts	N. Mex., Calif., Utah, Mich.	Md.
Pumice	Ariz., Oreg., Calif., Hawaii	Colo., Idaho, Kans., Mont., Nebr., Nev., N. Mex., Okla., Tex., Utah, Wash., Wyo.
Pyrites	Tenn., Pa., Colo., Ariz.	S.C.
Rare-earth metals	Calif., Fla.	
Salt	Tex., La., N.Y., Ohio	Ala., Calif., Colo., Kans., Mich., Nev., N. Mex., N. Dak., Okla., Utah, Va., W. Va.
Sand and gravel	Calif., Mich., N.Y., Ohio	All other States.
Silver	Idaho, Ariz., Mont., Utah	Alaska, Calif., Colo., Ky., Mich., Nev., N. Mex., N.Y., Oreg., Pa., S. Dak., Tenn., Wash., Wyo.
Sodium carbonate	Wyo., Calif.	
Sodium sulfate	Calif., Tex., Wyo.	
Staurolite	Fla.	
Stone	Pa., Calif., Ill., Tex.	All other States.
Sulfur (Frasch)	Tex., La.	
Sulfur, ore	Calif., Nev.	
Talc	N.Y., Calif., N.C., Vt.	Ala., Ark., Ga., Md., Mont., Nev., Pa., Tex., Va., Wash.
Tin	Calif., Colo., Alaska	
Titanium	N.Y., Fla., N.J., Va.	Idaho, S.C.
Tripoli	Ill., Okla., Pa.	
Tungsten	Calif., Colo., N.C., Nev.	Ariz., Idaho, Oreg.
Uranium	N. Mex., Colo., Utah, Wash.	Alaska, Ariz., Calif., Mont., Nev., N. Dak., Oreg., S. Dak., Tex., Wyo.
Vanadium	Colo., Utah, Idaho, Ariz.	N. Mex., Oreg., S. Dak., Wyo.
Vermiculite	Mont., S.C., Colo.	
Wollastonite	N.Y., Calif.	
Zinc	Tenn., N.Y., Idaho, Colo.	Ariz., Calif., Ill., Kans., Ky., Mo., Mont., Nev., N.J., N. Mex., Okla., Oreg., Pa., Utah, Va., Wash., Wis.
Zirconium	Fla.	

TABLE 4.—Value of mineral production in the United States and principal minerals produced in 1964

(Thousands)

State	Value	Rank	Percent of U.S. total	Principal minerals in order of value
Alabama	$235,690	20	1.15	Coal, cement, stone, petroleum.
Alaska	65,947	38	.32	Petroleum, sand and gravel, coal, gold.
Arizona	534,364	10	2.61	Copper, sand and gravel, cement, molybdenum.
Arkansas	174,789	26	.85	Petroleum, stone, bauxite, cement.
California	1,560,510	3	7.62	Petroleum, natural gas, cement, sand and gravel.
Colorado	316,011	17	1.54	Petroleum, molybdenum, coal, sand and gravel.
Connecticut	21,850	45	.11	Stone, sand and gravel, lime, feldspar.
Delaware	1,742	50	.01	Sand and gravel, stone, clays.
District of Columbia	82	51	(1)	Clays.
Florida	223,409	21	1.09	Phosphate rock, stone, cement, clays.
Georgia	127,958	28	.63	Clays, stone, cement, sand and gravel.
Hawaii	19,605	46	.10	Cement, stone, sand and gravel, pumice.
Idaho	86,262	32	.42	Silver, lead, zinc, phosphate rock.
Illinois	591,136	8	2.89	Coal, petroleum, stone, sand and gravel.
Indiana	211,783	23	1.03	Coal, cement, stone, petroleum.
Iowa	106,630	29	.52	Cement, stone, sand and gravel, gypsum.
Kansas	513,269	11	2.51	Petroleum, natural gas, cement, natural gas liquids.
Kentucky	444,379	15	2.17	Coal, petroleum, stone, natural gas.
Louisiana	2,785,007	2	13.60	Petroleum, natural gas, natural gas liquids, sulfur.
Maine	17,574	47	.09	Sand and gravel, cement, stone, peat.
Maryland	73,893	36	.36	Stone, cement, sand and gravel, coal.
Massachusetts	36,367	43	.18	Sand and gravel, stone, lime, clays.
Michigan	555,495	9	2.71	Iron ore, cement, copper, sand and gravel.
Minnesota	497,495	13	2.43	Iron ore, sand and gravel, stone, cement.
Mississippi	212,193	22	1.04	Petroleum, natural gas, sand and gravel, cement.
Missouri	189,305	25	.92	Stone, cement, lead, iron ore.
Montana	211,435	24	1.03	Petroleum, copper, sand and gravel, stone.
Nebraska	91,959	31	.45	Petroleum, sand and gravel, cement, stone.
Nevada	85,137	33	.42	Copper, sand and gravel, iron ore, diatomite.
New Hampshire	7,302	48	.04	Sand and gravel, stone, feldspar, clays.
New Jersey	78,172	35	.38	Stone, sand and gravel, zinc, iron ore.
New Mexico	720,124	7	3.52	Petroleum, potassium salts, natural gas, copper.
New York	288,445	18	1.41	Cement, stone, sand and gravel, salt.
North Carolina	56,470	40	.28	Stone, sand and gravel, cement, feldspar.
North Dakota	92,866	30	.45	Petroleum, sand and gravel, natural gas, coal.
Ohio	454,937	14	2.22	Coal, stone, cement, lime.
Oklahoma	881,270	5	4.30	Petroleum, natural gas, natural gas liquids, cement.
Oregon	64,269	39	.31	Sand and gravel, stone, cement, nickel.
Pennsylvania	902,050	4	4.41	Coal, cement, stone, iron ore.
Rhode Island	2,549	49	.01	Sand and gravel, stone, gem stones.
South Carolina	38,713	42	.19	Cement, stone, clays, sand and gravel.
South Dakota	52,824	41	.26	Gold, sand and gravel, cement, stone.
Tennessee	173,965	27	.85	Stone, zinc, cement, coal.
Texas	4,533,078	1	22.14	Petroleum, natural gas, natural gas liquids, cement.
Utah	391,430	16	1.91	Copper, petroleum, coal, uranium.
Vermont	26,127	44	.13	Stone, asbestos, sand and gravel, talc.
Virginia	237,415	19	1.16	Coal, stone, cement, sand and gravel.
Washington	80,977	34	.40	Sand and gravel, cement, stone, zinc.
West Virginia	822,691	6	4.02	Coal, natural gas, natural gas liquids, stone.
Wisconsin	70,007	37	.34	Sand and gravel, stone, cement, zinc.
Wyoming	504,846	12	2.47	Petroleum, natural gas, uranium, iron ore.
Total	20,471,803	--------	100.00	Petroleum, natural gas, coal, cement.

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[1] Less than 0.005 percent.

TABLE 5.—Mineral production[1] in the United States, by States

Mineral	1961		1962		1963		1964	
	Quantity	Value (thousands)	Quantity	Value (thousands)	Quantity	Value (thousands)	Quantity	Value (thousands)
ALABAMA								
Cement:[2]								
Portland thousand 376-pound barrels	12,445	$39,027	12,482	$40,164	12,218	$38,417	12,870	$40,108
Masonry thousand 280-pound barrels	2,006	6,156	2,187	6,521	2,386	7,242	2,574	7,794
Clays[3] thousand short tons	1,787	2,068	1,632	1,947	1,607	3,003	1,991	4,060
Coal (bituminous) do	12,915	90,903	12,880	95,149	12,359	91,243	14,435	[p] 102,267
Gem stones	------	------	------	------	(4)	2	------	------
Iron ore (usable) thousand long tons, gross weight	3,597	20,510	2,962	17,838	2,126	11,806	2,106	11,812
Lime thousand short tons	579	6,871	522	6,298	596	6,974	599	7,118
Natural gas million cubic feet	56	4	128	13	177	21	166	18
Petroleum (crude) thousand 42-gallon barrels	6,931	19,060	7,473	19,355	9,175	23,763	8,498	22,095
Sand and gravel thousand short tons	5,800	6,452	4,655	4,486	5,363	5,778	5,840	6,191
Stone[5] do	13,651	19,909	12,680	19,667	13,684	22,206	15,852	24,976
Value of items that cannot be disclosed: Native asphalt, bauxite, slag cement, clays (kaolin, bentonite 1964), scrap mica, sheet mica (1961-62), salt, stone (dimension limestone, dimension marble 1961, 1964, shell 1961, 1963-64, crushed sandstone 1961), and talc	XX	7,919	XX	8,347	XX	5,415	XX	9,251
Total	XX	218,879	XX	219,785	XX	215,870	XX	235,690
ALASKA								
Antimony ore and concentrate short tons, antimony content	------	------	------	------	------	------	14	$18
Coal (bituminous) thousand short tons	737	$5,868	871	$6,409	853	$5,910	745	5,008
Copper (recoverable content of ores, etc.) short tons	92	55	------	------	------	------	11	7
Gold (recoverable content of ores, etc.) troy ounces	114,216	3,998	165,259	5,784	99,573	3,485	58,416	2,045
Lead (recoverable content of ores, etc.) short tons	W	W	------	------	5	1	------	------
Mercury 76-pound flasks	4,129	816	3,719	711	400	76	303	95
Natural gas million cubic feet	631	129	2,184	467	4,498	1,111	6,272	1,719
Peat short tons	------	------	64	W	------	------	2,350	19
Petroleum (crude) thousand 42-gallon barrels	6,327	17,652	10,259	31,187	10,740	32,650	11,059	33,627
Sand and gravel thousand short tons	5,241	4,185	5,731	5,355	16,926	22,005	26,089	18,488
Silver (recoverable content of ores, etc.) thousand troy ounces	18	17	22	24	14	18	7	9
Value of items that cannot be disclosed: Gem stones, platinum-group metals, stone, tin (1964), uranium ore and vlaues indicated by symbol W	XX	2,033	XX	4,255	XX	2,584	XX	4,912
Total	XX	34,753	XX	54,192	XX	67,840	XX	65,947

See footnotes at end of table.

TABLE 5.—Mineral production [1] in the United States, by States—Continued

Mineral	1961		1962		1963		1964	
	Quantity	Value (thousands)	Quantity	Value (thousands)	Quantity	Value (thousands)	Quantity	Value (thousands)
ARIZONA								
Beryllium concentrate ... short tons, gross weight	8	$4	1	(6)	----	----	----	----
Clays [3] ... thousand short tons	165	240	139	$184	163	$203	168	$213
Copper (recoverable content of ores, etc.) ... short tons	587,053	352,232	644,242	396,853	660,977	407,162	690,988	450,524
Diatomite ... do	W	W	W	W	W	W	450	16
Gem stones	(4)	119	(4)	120	(4)	120	(4)	120
Gold (recoverable content of ores, etc.) ... troy ounces	145,959	5,109	137,207	4,802	140,030	4,901	153,676	5,379
Gypsum ... thousand short tons	W	W	W	W	W	W	147	770
Iron ore (usable) ... thousand long tons, gross weight	W	W	W	W	W	W	4	32
Lead (recoverable content of ores, etc.) ... short tons	5,937	1,223	6,966	1,282	5,815	1,256	6,147	1,611
Lime ... thousand short tons	167	2,686	174	2,914	181	3,048	177	2,920
Mercury ... 76-pound flasks	148	29	W	W	W	W	77	24
Molybdenum (content of concentrate) ... thousand pounds	4,878	6,232	4,412	5,864	5,553	7,584	6,296	9,532
Natural gas ... million cubic feet	----	----	230	27	1,334	161	2,025	241
Petroleum (crude) ... thousand 42-gallon barrels	73	W	39	W	68	W	64	W
Pumice ... thousand short tons	745	1,893	756	1,640	800	1,877	880	1,635
Sand and gravel ... do	17,688	16,175	15,579	17,404	15,037	14,466	18,116	20,868
Silver (recoverable content of ores, etc.) thousand troy ounces	5,120	4,733	5,454	5,917	5,373	6,873	5,811	7,513
Stone ... thousand short tons	3,582	4,626	4,333	6,616	3,257	5,069	3,759	6,283
Tungsten ore and concentrate short tons, 60-percent WO_3 basis	----	----	15	14	----	----	16	17
Uranium ore ... short tons	228,225	4,965	143,196	3,047	150,584	4,844	102,258	3,253
Vanadium (recoverable in ore and concentrate) ... do	W	W	632	W	222	W	W	575
Zinc (recoverable content of ores, etc.) ... do	29,585	6,804	32,888	7,564	25,419	5,846	24,690	6,716
Value of items that cannot be disclosed: Asbestos, cement, clays (bentonite, fire clay), feldspar, helium, manganiferous ore (1961), scrap mica, perlite, pyrites, and values indicated by symbol W	XX	18,925	XX	19,883	XX	[r] 17,705	XX	16,122
Total	XX	425,995	XX	474,131	XX	[r] 48,115	XX	534,364

ARKANSAS

Barite short tons	277,855	$2,630	258,691	$2,232	236,077	$2,161	233,455	$2,202
Bauxite long tons, dried equivalent	1,178,898	13,462	1,270,124	14,606	1,478,047	16,701	1,561,984	17,431
Clays thousand short tons	773	1,758	654	1,693	769	1,763	892	2,152
Coal (bituminous) do	395	2,888	256	1,809	221	1,505	212	1,503
Gem stones	(4)	19	(4)	15	(4)	42	(4)	33
Gypsum thousand short tons	167	531	83	261	W	W	W	W
Iron ore (usable) thousand long tons, gross weight	-----	-----	43	296	W	W	W	W
Lime thousand short tons	90	1,196	350	4,542	167	2,237	189	2,814
Natural gas million cubic feet	59,547	8,039	66,213	9,866	76,101	11,796	76,167	11,806
Natural gas liquids:								
Natural gasoline and cycle products thousand gallons	27,889	1,640	29,415	1,673	26,219	1,466	30,082	1,678
LP gases do	75,157	3,286	69,452	2,432	66,377	2,497	61,616	2,460
Petroleum (crude) thousand 42-gallon barrels	29,246	80,427	27,649	73,546	27,406	72,900	26,737	71,120
Sand and gravel thousand short tons	9,389	9,074	10,847	10,006	12,099	13,589	11,794	14,836
Stone do	12,029	12,402	20,611	19,866	18,913	22,727	20,241	26,172
Zinc (recoverable content of ores, etc.) short tons	37	9	211	49	-----	-----	-----	-----
Value of items that cannot be disclosed: Abrasive stones, bromine, cement, phosphate rock (1963-64), soapstone, and values indicated by symbol W	XX	10,906	XX	11,063	XX	17,900	XX	20,582
Total	XX	148,267	XX	153,955	XX	[r] 167,284	XX	174,789

See footnotes at end of table.

TABLE 5.—Mineral production [1] in the United States, by States—Continued

Mineral	1961		1962		1963		1964	
	Quantity	Value (thousands)	Quantity	Value (thousands)	Quantity	Value (thousands)	Quantity	Value (thousands)
CALIFORNIA								
Asbestos____short tons__	W	W	W	W	19, 591	$1, 547	55, 041	$4, 419
Barite____do____	21, 203	$295	6, 945	$133	5, 082	r 31	5, 604	45
Boron minerals____do____	602, 613	46, 936	646, 613	49, 336	700, 183	54, 981	776, 000	60, 871
Calcite (optical grade)____pounds__	------	------	------	------	------	------	4	2
Cement____thousand 376-pound barrels__	[2] 41, 090	[2] 129, 836	43, 667	139, 151	46, 278	147, 656	47, 204	149, 933
Clays____thousand short tons__	3, 041	6, 405	3, 137	7, 349	3, 395	8, 031	[3] 3, 651	[3] 8, 196
Copper (recoverable content of ores, etc.)____short tons__	1, 382	829	1, 162	716	916	564	1, 035	675
Feldspar____long tons__	W	W	W	W	75, 516	W	102, 264	W
Gem stones____	(4)	200	(4)	200	(4)	200	(4)	200
Gold (recoverable content of ores, etc.)____troy ounces__	97, 644	3, 418	106, 272	3, 720	86, 867	3, 040	71, 028	2, 486
Gypsum____thousand short tons__	1, 574	3, 733	1, 747	4, 113	1, 756	4, 222	1, 893	4, 539
Lead (recoverable content of ores, etc.)____short tons__	103	21	455	84	823	178	1, 546	405
Lime____thousand short tons__	503	9, 062	470	8, 454	487	8, 932	577	10, 312
Magnesium compounds from sea water and bitterns (partly estimated) short tons, MgO equivalent____	90, 534	6, 467	76, 445	6, 077	82, 397	6, 135	94, 739	7, 143
Mercury____76-pound flasks__	18, 688	3, 693	15, 951	3, 050	13, 592	2, 575	10, 291	3, 240
Mica, scrap____short tons__	950	12	W	W	977	14	W	W
Natural gas____million cubic feet__	556, 241	157, 416	564, 220	163, 624	646, 486	189, 420	664, 051	198, 551
Natural gas liquids:								
Natural gasoline and cycle products__thousand gallons__	762, 878	57, 645	716, 904	54, 460	715, 303	54, 188	720, 373	54, 088
LP gases____do____	424, 767	21, 805	407, 378	19, 294	393, 503	17, 329	352, 614	15, 893
Peat____short tons__	46, 348	501	33, 901	331	39, 873	450	35, 391	443
Petroleum (crude)____thousand 42-gallon barrels__	299, 609	728, 050	296, 590	741, 475	300, 908	746, 252	300, 009	729, 022
Pumice____thousand short tons__	610	2, 202	573	2, 615	460	2, 017	443	1, 937
Salt____do____	1, 601	W	1, 643	W	1, 716	W	1, 525	W
Sand and gravel____do____	110, 181	124, 111	107, 660	124, 922	112, 185	128, 178	112, 995	129, 333
Silver (recoverable content of ores, etc.) thousand troy ounces__	93	86	133	144	157	200	172	222
Stone____thousand short tons__	33, 850	50, 327	34, 776	54, 722	37, 977	58, 253	45, 805	63, 566
Sulfur ore____long tons__	W	W	W	W	785	4	520	3
Talc, soapstone, and pyrophyllite____short tons__	161, 068	1, 524	117, 912	1, 339	120, 452	1, 427	132, 601	1, 631
Wollastonite____do____	4, 075	42	W	W	3, 000	28	3, 625	36
Zinc (recoverable content of ores, etc.)____do____	304	70	322	74	101	23	143	39
Value of items that cannot be disclosed: Bromine, calcium-magnesium chloride, carbon dioxide, masonry cement (1961), clays (ball clay, fuller's earth 1964), coal (lignite), diatomite, fluorspar (1961), iodine, iron ore, lithium minerals, magnesite (1961), manganiferous ore (1962), molybdenum, perlite, platinum-group metals (crude), potassium salts, pyrites, (1961–62), rare-earth metal concentrates,								

sodium carbonates and sulfates, tin (1963-64), tungsten concentrate, uranium ore (1960, 1963-64), and values indicated by symbol W	XX	81,051	XX	81,957	XX	r 90,366	XX	113,280
Total	XX	1,435,737	XX	1,467,340	XX	r 1,526,241	XX	1,560,510
COLORADO								
Beryllium concentrate, short tons, gross weight	[11] 819	W	[11] 782	W	[11] 751	W	W	W
Carbon dioxide, natural, thousand cubic feet	167,872	$19	148,940	$15	224,856	$38	211,830	$36
Clay, thousand short tons	556	1,241	802	1,573	686	1,334	558	1,275
Coal (bituminous), do	3,678	22,787	3,379	19,999	3,690	21,888	4,355	23,427
Copper (recoverable content of ores, etc.), short tons	4,141	2,485	4,534	2,793	4,169	2,568	4,653	3,034
Feldspar, long tons	14,129	99	W	W	W	W	W	W
Gem stones	(4)	36	(4)	45	(4)	63	(4)	80
Gold (recoverable content of ores, etc.), troy ounces	67,515	2,363	48,882	1,711	33,605	1,176	42,122	1,474
Gypsum, thousand short tons	85	320	108	383	99	346	100	398
Iron ore (usable), thousand long tons, gross weight	27	190	W	W	W	W	35	231
Lead (recoverable content of ores, etc.), short tons	17,755	3,658	17,411	3,204	19,918	4,302	20,563	5,388
Lime, thousand short tons	75	1,319	93	1,518	128	2,104	138	2,193
Mica, scrap, short tons	600	10	142	2	440	7	-----	-----
Molybdenum (content of concentrate), thousand pounds	47,485	63,582	32,412	45,376	47,977	67,168	46,378	69,207
Natural gas, million cubic feet	108,142	12,544	101,826	11,812	105,705	12,367	114,312	13,489
Natural gas liquids:								
Natural gasoline, thousand gallons	76,880	3,627	60,558	3,826	56,869	3,191	52,400	2,845
LP gases, do	115,410	5,498	100,787	4,411	91,309	4,171	88,916	3,894
Peat, short tons	9,894	44	12,351	68	13,774	98	27,931	188
Petroleum (crude), thousand 42-gallon barrels	46,759	134,666	42,477	122,334	38,283	110,255	34,755	100,094
Pumice, thousand short tons	44	60	76	82	60	87	61	114
Sand and gravel, do	18,360	16,946	19,313	18,926	20,385	20,929	20,746	22,227
Silver (recoverable content of ores, etc.) thousand troy ounces	1,965	1,817	2,088	2,265	2,307	2,951	2,626	3,396
Stone, thousand short tons	2,451	5,301	2,353	5,597	2,510	5,693	3,217	6,805
Uranium ore, short tons	1,282,462	21,509	1,135,440	18,044	1,014,206	15,864	833,282	13,389
Vanadium (recoverable in ore and concentrate), do	4,149	W	3,742	W	3,047	W	3,312	9,916
Vermiculite, thousand short tons	-----	-----	W	W	(6)	1	(6)	1
Zinc (recoverable content of ores, etc.), short tons	42,647	9,809	43,351	9,971	48,109	11,065	53,682	14,602
Value of items that cannot be disclosed: Cement, fluorspar, perlite, pyrites, salt, tin, tungsten, and values indicated by symbol W	XX	36,278	XX	34,209	XX	29,478	XX	18,308
Total	XX	346,208	XX	308,164	XX	r 317,144	XX	316,011

See footnotes at end of table.

TABLE 5.—Mineral production [1] in the United States, by States—Continued

Mineral	1961		1962		1963		1964	
	Quantity	Value (thousands)	Quantity	Value (thousands)	Quantity	Value (thousands)	Quantity	Value (thousands)
CONNECTICUT								
Beryllium concentrate ____ short tons, gross weight__	2	$1	7	$4	---	---	---	---
Clays ____ thousand short tons__	[3] 149	[3] 260	[3] 179	[3] 287	189	$339	212	$262
Gem stones ____	(4)	9	(4)	8	(4)	8	(4)	8
Lime ____ thousand short tons__	33	589	35	635	35	666	39	689
Sand and gravel ____ do ____	7,499	6,633	10,208	9,244	10,503	9,343	10,088	9,437
Stone ____ do ____	5,206	8,616	5,090	8,816	5,318	9,612	5,864	10,764
Value of items that cannot be disclosed: Clays (kaolin 1961–62) feldspar, scrap mica, sheet mica (1961–62), and peat ____	XX	491	XX	760	XX	646	XX	690
Total ____	XX	16,599	XX	19,754	XX	20,614	XX	21,850
DELAWARE								
Clays ____ thousand short tons__	W	W	W	W	13	$13	11	$11
Gem stones ____ do ____	(4)	W	(4)	W	(4)	1	(4)	1
Sand and gravel ____ do ____	961	$970	1,755	$1,445	1,094	1,136	1,282	1,280
Value of items that cannot be disclosed: Other nonmetals and values indicated by symbol W ____	XX	83	XX	86	XX	191	XX	450
Total ____	XX	1,053	XX	1,531	XX	1,341	XX	1,742
FLORIDA								
Clays ____ thousand short tons__	513	$7,202	487	$6,741	538	$7,777	627	$8,405
Lime ____ do ____	W	W	W	W	126	1,996	117	1,814
Natural gas ____ million cubic feet__	29	5	29	6	35	7	40	5
Peat ____ short tons__	26,673	157	20,595	139	21,049	129	19,813	102
Petroleum (crude) ____ thousand 42-gallon barrels__	374	W	419	W	464	W	620	W
Phosphate rock ____ thousand long tons__	13,789	95,590	13,949	94,595	14,592	101,050	17,108	119,667
Sand and gravel ____ thousand short tons__	6,530	5,577	5,924	5,179	7,542	5,823	7,420	6,427
Stone ____ do ____	[5] 26,221	[5] 33,671	27,279	32,608	31,900	38,173	33,157	38,362
Value of items that cannot be disclosed: Cement, gem stones (1961, 1963), magnesium compounds, natural gas liquids, rare-earth metals concentrates, staurolite, stone (dimension limestone 1961), titanium concentrate, zirconium concentrate, and values indicated by symbol W ____	XX	45,919	XX	46,432	XX	46,665	XX	48,627
Total ____	XX	188,121	XX	185,700	XX	201,620	XX	223,409

GEORGIA

Barite...short tons	106,914	$2,046	108,829	$1,987	117,096	$2,013	109,228	$2,022
Clays...thousand short tons	3,569	42,025	3,801	47,462	4,208	54,024	4,365	58,899
Coal (bituminous)...do	4	22	8	28	5	16	4	15
Feldspar...long tons	31,128	692	35,692	795	W	W	W	W
Gem stones	(4)	W	(4)	W	(4)	1	----	----
Iron ore (usable)...thousand long tons, gross weight	162	835	215	1,118	260	1,304	354	1,752
Mica (sheet)...pounds	349	3	60	1	----	----	----	----
Peat...short tons	1,914	W	W	W	W	W	W	W
Sand and gravel...thousand short tons	3,150	3,049	3,429	3,365	3,817	3,922	4,159	4,311
Stone...do	15,854	38,077	19,555	42,037	19,582	46,044	22,730	46,532
Talc...short tons	47,950	98	45,940	96	42,000	93	40,400	135
Value of items that cannot be disclosed: Bauxite, cement, gem stones (1961–63), kyanite (1963–64), manganiferous ore (1961–63), scrap mica, and values indicated by symbol W	XX	9,464	XX	10,816	XX	12,059	XX	14,292
Total	XX	96,311	XX	107,705	XX	119,476	XX	127,958

HAWAII

Cement...thousand 376-pound barrels	1,077	$5,574	1,128	$6,055	1,483	$7,125	1,717	$8,877
Clays...thousand short tons	W	W	W	W	W	W	3	W
Gem stones	(4)	18	(4)	W	(4)	36	(4)	W
Lime...thousand short tons	14	354	15	386	12	428	9	321
Pumice...do	324	626	232	380	274	469	365	603
Salt...do	(6)	4	(6)	W	(6)	W	W	W
Sand and gravel...do	416	758	700	1,122	304	764	407	979
Stone...do	4,429	7,656	4,071	6,883	3,844	6,480	5,282	8,765
Value of items that cannot be disclosed: Other nonmetals and values indicated by symbol W	XX	----	XX	18	XX	5	XX	60
Total	XX	14,990	XX	14,844	XX	15,307	XX	19,605

See footnotes at end of table.

TABLE 5.—Mineral production [1] in the United States, by States—Continued

Mineral	1961		1962		1963		1964	
	Quantity	Value (thousands)	Quantity	Value (thousands)	Quantity	Value (thousands)	Quantity	Value (thousands)
IDAHO								
Antimony ore and concentrate short tons, antimony content	689	W	631	W	645	W	585	W
Clays thousand short tons	[3] 27	[3] $20	35	$70	[3] 31	[3] $15	[3] 29	[3] $25
Copper (recoverable content of ores, etc.) short tons	4,328	2,597	3,861	2,378	4,172	2,570	4,666	3,042
Gold (recoverable content of ores, etc.) troy ounces	5,718	200	5,845	205	5,477	192	5,677	199
Iron ore (usable) thousand long tons, gross weight	12	70	5	35	6	40	4	33
Lead (recoverable content of ores, etc.) short tons	71,476	14,724	84,058	15,467	75,759	16,364	71,312	18,684
Lime thousand short tons	47	658	68	801	60	874	W	W
Mercury 76-pound flasks	1,073	212	---	---	W	W	83	26
Peat short tons	W	W	W	W	W	W	900	8
Phosphate rock thousand long tons	1,440	7,984	1,912	10,635	1,700	10,589	W	W
Pumice thousand short tons	60	95	67	103	161	275	59	100
Sand and gravel do	7,305	6,793	14,321	13,029	12,433	10,615	9,582	8,691
Silver (recoverable content of ores, etc.) thousand troy ounces	17,576	16,249	17,772	19,283	16,711	21,375	16,483	21,313
Stone thousand short tons	1,873	3,111	1,381	2,698	1,168	2,217	1,144	2,773
Titanium concentrate short tons, gross weight	1,873	28	W	W	W	W	W	W
Tungsten concentrate short tons	W	W	---	---	---	---	11	8
Vanadium do	W	W	W	W	23	W	W	W
Zinc (recoverable content of ores, etc.) do	58,295	13,408	62,865	14,459	63,267	14,551	59,298	16,129
Value of items that cannot be disclosed: Barite, cement, clays (fire clay 1961, 1963-64, bentonite 1961, 1963-64, kaolin 1961, 1963-64), abrasive garnet, gem stones, scrap mica (1963-64), sheet mica (1962), perlite, uranium (1961-62), and values indicated by symbol W	XX	2,885	XX	3,451	XX	[r] 3,110	XX	15,231
Total	XX	69,034	XX	82,614	XX	[r] 82,787	XX	86,262

ILLINOIS

Cement:								
Portland ---- thousand 376-pound barrels	8,595	$28,301	9,145	$30,205	9,281	$30,577	9,790	$32,191
Masonry ---- thousand 280-pound barrels	461	1,420	440	1,320	472	1,440	596	2,038
Clays ---- thousand short tons	1,982	4,166	1,929	4,151	1,949	4,368	[3] 2,007	[3] 4,358
Coal (bituminous) ---- do	45,246	177,070	48,487	186,986	51,736	196,518	55,023	208,448
Fluorspar ---- short tons	116,908	5,956	132,830	6,392	132,060	6,547	127,454	6,452
Lead (recoverable content of ores, etc.) ---- do	3,430	707	3,610	664	2,901	627	2,180	571
Natural gas ---- million cubic feet	9,970	1,276	10,650	1,523	9,459	1,220	7,867	905
Natural gas liquids:								
Natural gasoline and cycle products -- thousand gallons	16,956	1,311	13,315	1,023	14,939	1,077	14,109	1,030
LP gases ---- do	340,284	16,495	327,616	13,812	337,278	14,714	312,173	13,758
Peat ---- short tons	6,597	30	W	W	W	W	W	W
Petroleum (crude) ---- thousand 42-gallon barrels	76,818	229,686	78,796	234,812	74,796	222,892	70,168	205,592
Sand and gravel ---- thousand short tons	31,353	35,098	34,122	38,981	31,746	36,431	34,880	39,966
Stone ---- do	36,361	47,939	41,293	54,411	40,293	52,217	42,987	56,553
Zinc (recoverable content of ores, etc.) ---- short tons	26,795	6,163	27,413	6,305	20,337	4,678	13,800	3,754
Value of items that cannot be disclosed: Clays (fuller's earth 1964), gem stones, lime, tripoli, and values indicated by symbol W ----	XX	11,775	XX	12,133	XX	13,656	XX	15,520
Total ----	XX	567,393	XX	592,718	XX	r 586,962	XX	591,136

INDIANA

Abrasive stones ---- short tons	5	$14	5	$15	5	$16	5	$16
Cement [2] ---- thousand 376-pound barrels	13,780	47,024	12,878	42,572	13,165	43,216	15,038	48,695
Clays ---- thousand short tons	1,362	2,446	1,450	2,255	1,546	2,347	1,545	2,264
Coal (bituminous) ---- do	15,106	58,815	15,709	60,079	15,100	57,120	15,075	57,246
Natural gas ---- million cubic feet	382	77	284	60	286	67	200	47
Peat ---- short tons	57,146	502	47,430	272	47,695	412	66,568	543
Petroleum (crude) ---- thousand 42-gallon barrels	11,500	34,270	12,077	35,989	11,902	35,230	11,283	32,157
Sand and gravel ---- thousand short tons	19,577	16,898	21,261	18,692	22,840	20,683	24,416	21,811
Stone ---- do	18,001	33,062	18,709	34,653	19,667	35,616	22,318	39,978
Value of items that cannot be disclosed: Cement (masonry 1961, 1964), gem stones (1961–63), gypsum, and values indicated by symbol W ----	XX	8,437	XX	8,839	XX	r 9,259	XX	9,026
Total ----	XX	201,545	XX	203,426	XX	r 203,966	XX	211,783

See footnotes at end of table.

TABLE 5.—Mineral production [1] in the United States, by States—Continued

Mineral	1961		1962		1963		1964	
	Quantity	Value (thousands)	Quantity	Value (thousands)	Quantity	Value (thousands)	Quantity	Value (thousands)
IOWA								
Cement:								
Portland ---- thousand 376-pound barrels	12, 108	$41, 718	12, 261	$42, 417	12, 495	$42, 891	13, 607	$46, 398
Masonry ---- thousand 280-pound barrels	557	1, 843	568	1, 786	551	1, 754	585	1, 847
Clays ---- thousand short tons	1, 044	1, 426	1, 039	1, 427	1, 064	1, 405	1, 008	1, 254
Coal (bituminous) ---- do	927	3, 323	1, 130	4, 026	1, 213	4, 244	973	3, 447
Gypsum ---- do	1, 239	5, 276	1, 256	5, 318	1, 282	5, 667	1, 287	5, 821
Sand and gravel ---- do	13, 391	11, 651	13, 797	12, 474	14, 168	12, 845	13, 890	13, 546
Stone ---- do	22, 018	28, 916	21, 618	28, 244	20, 904	27, 788	23, 935	33, 038
Value of items that cannot be disclosed: Gem stones, lime, peat, and petroleum	XX	845	XX	869	XX	1, 076	XX	1, 279
Total	XX	94, 998	XX	96, 561	XX	97, 670	XX	106, 630
KANSAS								
Cement:								
Portland ---- thousand 376-pound barrels	8, 028	$25, 605	8, 058	$25, 134	8, 201	$25, 372	8, 483	$25, 959
Masonry ---- thousand 280-pound barrels	379	1, 156	392	1, 156	387	1, 183	384	1, 173
Clays ---- thousand short tons	954	1, 225	895	1, 091	893	1, 104	785	935
Coal (bituminous) ---- do	664	3, 102	915	4, 249	1, 169	5, 311	1, 263	5, 749
Helium ---- thousand cubic feet	23, 251	434	42, 305	1, 478	46, 177	1, 616	47, 332	1, 657
Lead (recoverable content of ores, etc.) ---- short tons	1, 449	298	970	178	1, 027	222	1, 185	310
Lime ---- thousand short tons	15	193	5	59	----	----	----	----
Natural gas ---- million cubic feet	649, 083	81, 135	694, 352	86, 100	732, 946	97, 482	768, 246	96, 031
Natural gas liquids:								
Natural gasoline ---- thousand gallons	132, 180	5, 790	151, 360	7, 696	165, 370	9, 811	162, 725	8, 713
LP gases ---- do	135, 643	5, 916	166, 769	6, 295	395, 877	15, 481	512, 747	18, 121
Petroleum (crude) ---- thousand 42-gallon barrels	112, 241	324, 376	112, 076	326, 141	109, 107	317, 501	106, 252	310, 256
Salt [3] ---- thousand short tons	913	11, 409	944	11, 654	924	11, 993	930	11, 799
Sand and gravel ---- do	11, 366	7, 781	11, 552	8, 039	12, 062	8, 676	12, 968	9, 108
Stone ---- do	[5] 12, 328	[5] 16, 411	[5] 13, 527	[5] 17, 274	13, 558	18, 483	14, 138	18, 912
Zinc (recoverable content of ores, etc.) ---- short tons	2, 446	563	3, 943	907	3, 508	807	4, 665	1, 269
Value of items that cannot be disclosed: Natural cement, gypsum, pumice, salt (brine), and stone (crushed sandstone 1961–62)	XX	3, 204	XX	3, 625	XX	3, 260	XX	3, 277
Total	XX	488, 598	XX	501, 076	XX	518, 302	XX	513, 269

KENTUCKY

Barite short tons	3,304	$30	4,097	$36	5,812	$85	6,014	$96
Clays [3] thousand short tons	906	2,406	936	2,158	984	2,397	920	1,801
Coal (bituminous) do	63,032	256,158	69,212	270,875	77,350	295,743	82,747	309,896
Fluorspar short tons	31,169	1,420	33,830	1,492	35,072	1,537	38,214	1,693
Lead (recoverable content of ores, etc.) do	656	135	743	137	831	179	858	225
Natural gas million cubic feet	70,937	17,592	70,241	17,419	74,634	17,838	77,360	18,257
Petroleum (crude) thousand 42-gallon barrels	18,344	54,482	17,789	52,478	18,344	53,564	19,772	56,746
Sand and gravel thousand short tons	5,582	5,540	6,137	5,378	6,480	6,071	6,560	6,297
Silver (recoverable content of ores, etc.) thousand troy ounces	2	2	1	2	2	2	2	2
Stone thousand short tons	17,085	23,309	19,472	27,682	24,689	34,571	[5] 21,868	[5] 29,594
Zinc (recoverable content of ores, etc.) short tons	1,147	264	1,172	270	1,461	336	2,063	561
Value of items that cannot be disclosed: Cement, ball clay, gem stones (1961–63), natural gas liquids, and stone (dimension sandstone 1964)	XX	22,450	XX	20,609	XX	20,370	XX	19,211
Total	XX	383,788	XX	398,536	XX	[r] 432,693	XX	444,379

LOUISIANA

Clays thousand short tons	645	$645	638	$641	655	$655	780	$797
Lime do	636	6,292	624	6,519	657	6,862	725	8,312
Natural gas million cubic feet	3,271,857	611,837	3,525,456	694,515	3,928,427	777,829	4,175,412	793,328
Natural gas liquids:								
Natural gasoline and cycle products thousand gallons	931,176	61,714	1,010,137	74,726	1,143,707	81,332	1,352,980	91,931
LP gases do	806,559	33,214	862,772	29,037	1,113,670	41,043	1,247,484	45,935
Petroleum (crude) thousand 42-gallon barrels	424,962	1,338,160	477,153	1,502,568	515,057	1,608,120	549,698	1,709,622
Salt thousand short tons	4,722	23,357	5,248	27,407	6,199	30,450	6,401	36,056
Sand and gravel do	12,042	14,833	12,040	14,817	12,500	14,701	13,594	15,253
Stone [5] do	4,641	7,656	5,711	8,067	5,408	7,961	5,459	7,228
Sulfur (Frasch process) thousand long tons	2,352	55,164	2,262	49,772	2,445	48,905	2,733	54,996
Value of items that cannot be disclosed: Cement, gypsum, and stone (crushed miscellaneous)	XX	15,807	XX	18,554	XX	20,531	XX	21,549
Total	XX	2,168,679	XX	2,426,623	XX	[r] 2,638,389	XX	2,785,007

See footnotes at end of table.

TABLE 5.—Mineral production [1] in the United States, by States—Continued

Mineral	1961		1962		1963		1964	
	Quantity	Value (thousands)	Quantity	Value (thousands)	Quantity	Value (thousands)	Quantity	Value (thousands)
MAINE								
Beryllium concentrate______short tons, gross weight__	5	$3	W	W	------	------	------	------
Clays______thousand short tons__	43	51	48	$63	42	$55	45	$58
Gem stones______	(4)	20	(4)	25	(4)	25	(4)	35
Mica:								
Scrap______short tons__	80	2	15	(6)	------	------	------	------
Sheet______pounds__	9,680	88	2,017	16	------	------	------	------
Peat______short tons__	------	------	1,250	47	W	W	6,350	171
Sand and gravel______thousand short tons__	8,921	3,796	10,014	4,013	11,195	4,673	13,552	6,463
Stone______do____	998	4,694	1,127	4,249	947	3,581	1,414	4,506
Value of items that cannot be disclosed: Cement, feldspar, and values indicated by symbol W______	XX	6,961	XX	6,534	XX	5,770	XX	6,341
Total______	XX	15,615	XX	14,947	XX	14,104	XX	17,574
MARYLAND								
Clays______thousand short tons__	581	$997	593	$899	580	$897	[3] 635	[3] $798
Coal (bituminous)______do____	757	2,868	821	3,168	1,162	4,330	1,136	4,511
Gem stones______	(4)	3	(4)	3	(4)	3	(4)	3
Natural gas______million cubic feet__	3,578	973	2,472	667	1,633	439	1,381	366
Sand and gravel______thousand short tons__	12,404	16,894	12,762	16,816	13,310	16,063	15,041	18,071
Stone______do____	10,007	20,373	11,610	22,595	13,012	26,407	13,348	26,715
Value of items that cannot be disclosed: Cement, ball clay (1964), diatomite (1962-63), lime, greensand marl, peat, potassium salts, and talc and soapstone______	XX	20,750	XX	22,481	XX	22,111	XX	23,429
Total______	XX	62,858	XX	66,629	XX	70,250	XX	73,893

MASSACHUSETTS

Clays thousand short tons	104	$85	125	$96	157	$213	138	$174
Gem stones	(4)	2	(4)	2	(4)	2	(4)	2
Lime thousand short tons	145	2,307	148	2,337	145	2,426	171	2,703
Sand and gravel do	18,061	14,958	17,566	15,026	19,905	15,592	21,341	16,794
Stone do	5,210	13,399	4,985	12,541	5,570	14,396	6,519	16,663
Value of items that cannot be disclosed: Nonmetals	XX	38	XX	33	XX	32	XX	31
Total	XX	30,789	XX	30,035	XX	32,661	XX	36,367

MICHIGAN

Cement:								
Portland thousand 376-pound barrels	21,948	$75,172	22,682	$73,267	25,016	$76,944	26,745	$84,316
Masonry thousand 280-pound barrels	1,515	4,467	1,517	4,335	1,684	4,519	1,865	4,954
Clays thousand short tons	1,817	1,975	1,751	1,917	1,958	2,149	2,385	2,592
Copper (recoverable content of ores, etc.) short tons	70,245	42,147	74,099	45,645	75,262	46,361	69,040	45,014
Gypsum thousand short tons	1,295	5,095	1,278	4,791	1,315	4,938	1,421	5,263
Iron ore (usable) thousand long tons, gross weight	9,384	87,604	9,422	85,597	10,789	107,201	13,871	143,979
Lime thousand short tons	1,190	15,665	1,153	15,371	1,371	18,431	1,430	19,246
Magnesium compounds from sea water and brine (except for metal) short tons, MgO equivalent	W	W	W	W	266,740	23,062	306,494	23,385
Manganiferous ore (5 to 35 percent Mn) short tons, gross weight	17,083	W	----	----	152,957	W	----	----
Natural gas million cubic feet	27,697	5,844	28,987	6,174	32,850	8,902	31,558	7,984
Peat short tons	210,376	2,009	257,693	2,277	251,809	2,413	269,074	2,412
Petroleum (crude) thousand 42-gallon barrels	18,901	55,191	17,114	48,775	15,972	45,520	15,601	43,839
Salt thousand short tons	3,885	31,284	4,274	33,343	4,244	33,656	4,345	35,711
Sand and gravel do	54,603	47,790	47,563	42,029	50,458	43,433	51,921	44,405
Silver (recoverable content of ores, etc.) thousand troy ounces	----	----	401	436	339	434	349	452
Stone thousand short tons	28,731	30,103	28,440	29,055	30,316	32,065	34,650	37,002
Value of items that cannot be disclosed: Bromine, calcium-magnesium chloride, gem stones, iodine, natural gas liquids, potassium salts, and values indicated by symbol W	XX	46,306	XX	53,500	XX	42,001	XX	54,941
Total	XX	450,652	XX	446,512	XX	r 492,029	XX	555,495

See footnotes at end of table.

TABLE 5.—Mineral production [1] in the United States, by States—Continued

Mineral	1961		1962		1963		1964	
	Quantity	Value (thousands)	Quantity	Value (thousands)	Quantity	Value (thousands)	Quantity	Value (thousands)
MINNESOTA								
Clays thousand short tons	[3] 176	[3] $241	203	$291	[3] 199	[3] $298	[3] 213	[3] $319
Iron ore (usable) thousand long tons, gross weight	44,699	407,152	44,295	385,997	45,435	408,486	49,626	449,289
Manganiferous ore (5 to 35 percent Mn) short tons, gross weight	181,835	W	292,779	W	347,336	W	188,481	W
Peat short tons	11,091	181	14,386	307	8,110	294	19,188	405
Sand and gravel thousand short tons	30,690	24,143	29,399	22,656	30,462	23,318	35,817	25,907
Stone do	3,957	9,975	3,803	10,360	3,898	11,027	3,588	12,297
Value of items that cannot be disclosed: Abrasive stones, cement, fire clay (1961, 1963–64), gem stones, lime, and values indicated by symbol W	XX	9,222	XX	9,325	XX	10,120	XX	9,278
Total	XX	450,914	XX	428,936	XX	453,543	XX	497,495
MISSISSIPPI								
Clays thousand short tons	1,104	$5,034	1,129	$5,742	1,235	$5,968	1,331	$6,130
Natural gas million cubic feet	172,543	32,093	170,271	32,351	176,807	31,825	181,414	31,385
Natural gas liquids:								
Natural gasoline and cycle products thousand gallons	25,135	1,625	25,891	1,616	28,757	1,755	27,485	1,644
LP gases do	15,510	700	20,401	732	24,541	956	23,277	780
Petroleum (crude) thousand 42-gallon barrels	54,688	154,220	55,713	154,882	58,619	161,788	56,777	151,595
Sand and gravel thousand short tons	5,920	5,903	7,001	7,262	6,825	7,056	7,825	8,569
Stone do	913	1,044	1,199	1,266	1,267	1,267	1,553	1,557
Value of items that cannot be disclosed: Certain nonmetals	XX	7,961	XX	9,030	XX	[r] 9,579	XX	10,533
Total	XX	208,580	XX	212,881	XX	[r] 220,194	XX	212,193

MISSOURI

Asphalt, native..........short tons..	W	W	W	W	1,779	$15	1,522	$13
Barite..........do....	227,323	$3,052	303,945	$3,994	286,750	3,680	266,814	3,451
Cement:								
Portland..........thousand 376-pound barrels..	11,839	41,142	12,739	44,004	12,402	41,640	12,378	42,618
Masonry..........thousand 280-pound barrels..	437	1,398	455	1,457	417	1,345	334	1,046
Clays..........thousand short tons..	2,132	5,040	2,053	5,033	1,746	4,467	1,966	4,874
Coal (bituminous)..........do....	2,938	12,567	2,896	12,057	3,174	13,196	3,254	13,285
Copper (recoverable content of ores, etc.)..........short tons..	1,479	887	2,752	1,695	1,816	1,119	2,059	1,343
Iron ore (usable)..........thousand long tons, gross weight..	341	3,633	346	3,188	345	3,085	1,116	14,907
Lead (recoverable content of ores, etc.)..........short tons..	98,785	20,350	60,982	11,221	79,844	17,246	120,148	31,479
Lime..........thousand short tons..	1,173	13,873	1,176	13,703	1,240	14,386	1,219	14,328
Natural gas..........million cubic feet..	90	22	92	23	100	27	108	26
Petroleum (crude)..........thousand 42-gallon barrels..	72	W	55	W	53	150	65	163
Sand and gravel..........thousand short tons..	9,371	10,688	10,304	11,572	10,653	12,260	11,483	13,380
Silver (recoverable content of ores, etc.) thousand troy ounces..	12	11	491	533	132	168	----------	----------
Stone..........thousand short tons..	25,631	36,577	28,876	44,006	30,885	46,130	31,487	47,984
Zinc (recoverable content of ores, etc.)..........short tons..	5,847	1,345	2,792	642	321	74	1,501	408
Value of items that cannot be disclosed: Cobalt (1961), gem stones (1961–62), nickel (1961), and values indicated by symbol W..........	XX	703	XX	179	XX	----------	XX	----------
Total..........	XX	151,288	XX	153,307	XX	[r]158,988	XX	189,305

See footnotes at end of table.

TABLE 5.—Mineral production [1] in the United States, by States—Continued

Mineral	1961		1962		1963		1964	
	Quantity	Value (thousands)	Quantity	Value (thousands)	Quantity	Value (thousands)	Quantity	Value (thousands)
MONTANA								
Chromite.......short tons, gross weight..	[9] 82,000	[9] $2,939	--------	--------	--------	--------	--------	--------
Clays [3].......thousand short tons..	55	76	56	$77	38	$45	49	$59
Coal (bituminous and lignite).......do....	371	1,207	382	1,140	343	967	346	925
Copper (recoverable content of ores, etc.).......short tons..	104,000	62,400	94,021	57,917	79,762	49,133	103.806	67,682
Fluorspar.......do....	14,905	W	W	W	W	W	W	W
Gold (recoverable content of ores, etc.).......troy ounces..	35,377	1,238	24,387	854	18,520	648	29,115	1,019
Iron ore (usable).......thousand long tons, gross weight..	34	209	9	62	13	89	15	99
Lead (recoverable content of ores, etc.).......short tons..	2,643	544	6,121	1,126	5,000	1,080	4,538	1,189
Lime.......thousand short tons..	118	986	104	1,049	114	1,290	136	1,385
Manganese ore (35 percent or more Mn) short tons, gross weight..	17,515	1,372	24,758	W	5,260	W	20,264	W
Manganiferous ore (5 to 35 percent Mn).......do....	2,236	33	2,264	29	1,688	W	3,638	W
Natural gas.......million cubic feet..	33,901	2,509	29,955	2,217	30,026	2,253	25,188	1,965
Peat.......short tons..	7,385	112	W	W	W	W	W	W
Petroleum (crude).......thousand 42-gallon barrels..	30,906	74,793	31,648	76,690	30,870	75,323	30,647	74,621
Sand and gravel.......thousand short tons..	14,702	13,506	18,473	17,642	14,319	13,756	16,017	17,840
Silver (recoverable content of ores, etc.) thousand troy ounces..	3,490	3,227	4,561	4,948	4,242	5,426	5,290	6,840
Stone.......thousand short tons..	1,512	1,849	996	1,708	6,109	7,081	7,345	8,477
Uranium ore.......short tons..	729	10	W	W	W	W	W	W
Zinc (recoverable content of ores, etc.).......do....	10,262	2,360	37,678	8,666	32,941	7,576	29,059	7,904
Value of items that cannot be disclosed: Barite, cement, chromite,[9] clays (fire clay, bentonite 1964), gem stones, gypsum, sheet mica (1961–62), natural gas liquids, phosphate rock, pumice (1964), rare-earth metal concentrates (1962), talc, tungsten (1961–62), vermiculite, and values indicated by symbol W.......	XX	14,863	XX	16,531	XX	[r] 17,351	XX	21,430
Total.......	XX	184,233	XX	190,656	XX	[r] 182,018	XX	211,435

NEBRASKA

Clays thousand short tons	146	$148	142	$142	148	$148	143	$143
Gem stones	(4)	5	(4)	5	(4)	5	(4)	5
Natural gas million cubic feet	15,743	2,629	14,880	2,708	13,051	2,454	11,155	1,707
Natural gas liquids:								
Natural gasoline thousand gallons	W	W	12,239	809	10,119	687	9,587	627
LP gases do	W	W	28,718	1,329	25,931	1,207	24,556	1,092
Petroleum (crude) thousand 42-gallon barrels	24,369	69,452	24,894	70,450	21,846	61,824	19,113	51,605
Sand and gravel thousand short tons	10,094	8,250	12,853	9,797	11,166	10,680	14,641	15,748
Stone do	3,622	6,324	3,670	6,626	3,700	6,192	3,779	6,417
Value of items that cannot be disclosed: Cement, lime, pumice, and values indicated by symbol W	XX	18,637	XX	16,507	XX	15,710	XX	14,615
Total	XX	105,445	XX	108,373	---	[r] 98,907	XX	91,959

NEVADA

Antimony ore and concentrate short tons, antimony content	---	---	---	---	---	---	33	$20
Barite short tons	129,524	$863	137,727	$954	120,450	$760	148,974	1,261
Copper (recoverable content of ores, etc.) do	78,022	46,813	82,602	50,883	81,738	50,351	67,272	43,861
Fluorspar do	18,129	357	W	W	W	W	W	W
Gem stones	(4)	100	(4)	100	(4)	100	(4)	100
Gold (recoverable content of ores, etc.) troy ounces	54,165	1,896	62,863	2,200	98,879	3,461	90,469	3,166
Gypsum thousand short tons	729	2,625	817	2,952	890	3,216	799	2,894
Iron ore (usable) thousand long tons, gross weight	845	4,608	617	3,238	772	3,921	911	5,048
Lead (recoverable content of ores, etc.) short tons	1,791	369	771	142	1,126	243	809	212
Manganese ore (35 percent or more Mn) short tons, gross weight	28,573	1,852	---	---	---	---	---	---
Mercury 76-pound flasks	7,486	1,480	6,573	1,257	4,944	937	3,262	1,027
Perlite short tons	29,544	240	25,067	205	22,910	192	15,603	135
Petroleum (crude) thousand 42-gallon barrels	154	W	141	W	118	W	255	W
Sand and gravel thousand short tons	7,095	7,443	7,850	9,655	9,688	10,513	14,142	14,427
Silver (recoverable content of ores, etc.) thousand troy ounces	388	359	245	266	215	275	172	223
Stone thousand short tons	677	1,576	722	1,220	639	1,101	788	1,396
Sulfur ore long tons	W	W	W	W	586	11	274	5
Talc and soapstone short tons	3,090	33	6,157	55	4,243	50	5,322	58
Tungsten ore and concentrate short tons, 60-percent WO_3 basis	W	W	156	234	W	W	W	W
Zinc (recoverable content of ores, etc.) short tons	453	104	281	65	571	131	582	158
Value of items that cannot be disclosed: Clays, diatomite, lime, magnesite, molybdenum, peat (1964), pumice, salt, uranium ore (1961, 1963–64), and values indicated by symbol W	XX	10,815	XX	9,648	XX	[r] 10,215	XX	11,146
Total	XX	81,533	XX	83,074	XX	[r] 85,477	XX	85,137

TABLE 5.—Mineral production [1] in the United States, by States—Continued

Mineral	1961		1962		1963		1964	
	Quantity	Value (thousands)	Quantity	Value (thousands)	Quantity	Value (thousands)	Quantity	Value (thousands)
NEW HAMPSHIRE								
Beryllium concentrate short tons, gross weight	23	$14	7	$4	---	---	---	---
Clays thousand short tons	30	30	37	37	r 47	r $40	46	$40
Feldspar long tons	10,290	62	W	W	W	W	W	W
Mica:								
Sheet pounds	105,943	1,009	37,508	396	---	---	---	---
Scrap short tons	669	20	411	11	---	---	---	---
Peat do	15	W	---	---	---	---	---	---
Sand and gravel thousand short tons	7,701	3,627	8,260	4,119	7,581	4,376	8,768	4,996
Stone do	117	684	154	1,368	137	1,566	202	2,138
Value of items that cannot be disclosed: Other nonmetals and values indicated by symbol W	XX	20	XX	97	XX	109	XX	128
Total	XX	5,466	XX	6,032	XX	r 6,091	XX	7,302
NEW JERSEY								
Clays thousand short tons	657	$1,681	584	$1,476	498	$1,392	500	$1,441
Gem stones	(4)	9	(4)	9	(4)	9	(4)	10
Peat short tons	21,257	212	29,099	247	23,685	241	W	W
Sand and gravel thousand short tons	12,257	20,895	13,728	21,230	16,672	25,245	17,661	27,079
Stone do	11,315	24,539	14,214	28,979	11,229	25,654	12,326	28,461
Zinc (recoverable content of ores, etc.) [10] short tons	112	26	15,309	3,559	32,738	7,855	32,926	8,935
Value of items that cannot be disclosed: Iron ore, lime, magnesium compounds, manganiferous residuum, greensand marl, titanium concentrate (ilmenite 1962–64) and values indicated by symbol W	XX	11,908	XX	10,186	XX	12,880	XX	12,246
Total	XX	59,270	XX	65,686	XX	73,276	XX	78,172

Barite short tons	600	$10	252	$4	600	$6	W	W
Beryllium concentrate short tons, gross weight	24	12	34	19	------	------	------	------
Carbon dioxide, natural thousand cubic feet	242,903	24	826,810	74	854,339	63	816,168	$61
Clays thousand short tons	[3] 67	[3] 165	52	156	W	140	[3] 104	[3] 167
Coal (bituminous) do	412	2,477	677	2,595	1,945	5,629	2,969	9,763
Copper (recoverable content of ores, etc.) short tons	79,606	47,764	82,683	50,933	83,037	51,151	86,104	56,140
Fluorspar do	------	------	------	------	------	------	137	3
Gem stones	(4)	46	(4)	45	(4)	45	(4)	45
Gold (recoverable content of ores, etc.) troy ounces	6,201	217	7,529	264	7,805	273	6,110	214
Gypsum thousand short tons	105	386	151	564	179	656	W	W
Helium thousand cubic feet	42,224	762	27,377	958	79,624	2,787	84,526	2,958
Iron ore (usable) thousand long tons, gross weight	(6)	W	9	121	W	W	W	W
Lead (recoverable content of ores, etc.) short tons	2,332	480	1,134	209	1,014	219	1,626	426
Lime thousand short tons	25	350	29	403	27	377	25	352
Manganese ore (35 percent or more Mn) short tons, gross weight	------	------	W	W	5,362	137	5,794	149
Manganiferous ore (5 to 35 percent Mn) do	W	W	W	W	41,144	W	46,657	300
Mica: Scrap short tons	1,800	52	5,731	140	W	W	6,922	105
Natural gas million cubic feet	789,662	86,073	804,612	92,530	808,377	96,197	878,720	101,932
Natural gas liquids:								
Natural gasoline and cycle products thousand gallons	301,404	18,619	273,969	16,775	291,388	17,555	356,047	21,570
LP gases do	656,751	24,154	661,330	20,359	728,200	21,801	739,190	21,641
Perlite short tons	245,654	2,159	258,164	2,143	259,113	2,212	286,329	2,568
Petroleum (crude) thousand 42-gallon barrels	112,553	322,142	109,328	314,883	109,941	316,574	113,863	326,565
Potassium salts thousand short tons, K_2O equivalent	2,523	96,380	2,208	85,124	[r] 2,643	[r] 101,458	2,675	104,866
Pumice thousand short tons	339	879	308	741	322	850	260	760
Salt do	33	284	43	334	[r] 54	[r] 472	62	559
Sand and gravel do	12,523	10,049	6,889	8,021	8,402	12,843	8,781	10,160
Silver (recoverable content of ores, etc.) thousand troy ounces	283	261	302	327	256	328	242	313
Stone thousand short tons	1,853	2,206	2,004	2,782	2,509	4,236	2,760	4,244
Uranium ore short tons	3,631,036	62,482	3,478,238	63,504	2,304,577	41,372	2,093,350	38,203
Vanadium (recoverable in ore and concentrate) do	W	W	W	W	23	W	W	154
Zinc (recoverable content of ores, etc.) do	22,900	5,267	22,015	5,063	12,938	2,976	29,833	8,115
Value of items that cannot be disclosed: Cement, fire clay (1961, 1964), molybdenum, magnesium compounds (1961), sheet mica (1962, and values indicated by symbol W	XX	7,213	XX	6,743	XX	8,249	XX	7,791
Total	XX	690,913	XX	675,814	XX	[r] 688,606	XX	720,124

See footnotes at end of table.

TABLE 5.—Mineral production [1] in the United States, by States—Continued

Mineral	1961		1962		1963		1964	
	Quantity	Value (thousands)	Quantity	Value (thousands)	Quantity	Value (thousands)	Quantity	Value (thousands)
NEW YORK								
Clays, thousand short tons	1,037	$1,373	1,397	$1,618	1,598	$2,186	1,499	$1,993
Emery, short tons	6,180	106	4,316	71	6,732	119	9,214	172
Gem stones	(4)	10	(4)	10	(4)	10	(4)	10
Gypsum, thousand short tons	663	3,441	601	3,122	647	3,339	653	3,321
Iron ore (usable), thousand long tons, gross weight	1,973	25,548	2,099	24,953	W	W	W	W
Lead (recoverable content of ores, etc.), short tons	879	181	1,063	196	1,009	218	732	192
Natural gas, million cubic feet	5,742	1,694	4,262	1,198	3,962	1,169	3,125	963
Peat, short tons	11,209	123	14,400	113	21,358	178	32,574	261
Petroleum (crude), thousand 42-gallon barrels	1,658	7,892	1,589	7,309	1,679	7,707	1,874	8,321
Salt, thousand short tons	4,149	30,761	4,456	32,236	4,782	34,228	4,816	34,216
Sand and gravel, do	28,043	30,471	29,447	31,346	37,381	37,274	39,282	38,583
Silver (recoverable content of ores, etc.), thousand troy ounces	41	37	19	21	20	25	13	17
Stone, thousand short tons	26,951	43,734	27,589	47,256	26,611	44,549	29,141	46,669
Zinc (recoverable content of ores, etc.), short tons	54,763	12,595	53,654	12,340	53,495	12,304	60,754	16,525
Value of items that cannot be disclosed: Beryllium concentrate (1961), cement, abrasive garnet, lime, talc, titanium concentrate, wollastonite, and values indicated by symbol W	XX	75,867	XX	79,183	XX	115,768	XX	137,202
Total	XX	233,833	XX	240,972	XX	[r] 259,074	XX	288,445
NORTH CAROLINA								
Abrasive stones (millstones), short tons	(4)	$3	(4)	$2	(4)	$2	----------	----------
Clays [3], thousand short tons	2,603	1,669	2,731	1,782	2,735	1,761	3,199	$2,064
Feldspar, long tons	251,858	2,477	244,708	2,373	267,654	2,821	324,149	3,085
Gem stones	(4)	6	(4)	2	(4)	14	(4)	15
Gold (recoverable content of ores, etc.), troy ounces	2,094	73	460	16	33	1	----------	----------
Iron ore (usable), thousand long tons	W	1	1	13	1	10	----------	----------
Lead (recoverable content of ores, etc.), short tons	318	66	219	40	62	13	----------	----------
Mica:								
Scrap, do	53,615	1,010	61,983	1,384	61,598	1,497	64,010	2,027
Sheet, pounds	390,870	2,237	320,305	867	92,961	13	242,662	58
Phosphate rock, thousand long tons	----------	----------	----------	----------	----------	----------	6	41
Sand and gravel, thousand short tons	9,779	8,467	12,516	11,457	11,028	10,132	11,150	10,404
Silver (recoverable content of ores, etc.), thousand troy ounces	170	157	100	109	27	34	----------	----------
Stone, thousand short tons	15,921	25,262	19,308	29,533	15,701	25,683	[5] 17,943	[5] 30,378

Talc and pyrophyllite short tons	90,711	367	100,298	433	106,652	446	106,035	495
Zinc (recoverable content of ores, etc.) do					13	3		
Value of items that cannot be disclosed: Asbestos, barite (1961), cement (1963–64), clay (kaolin), copper (1961–63), lithium minerals, olivine, stone (crushed and dimension marble and dimension slate 1964), tungsten concentrate, and values indicated by symbol W	XX	8,329	XX	6,586	XX	[r] 2,095	XX	7,903
Total	XX	50,124	XX	54,597	XX	[r] 44,525	XX	56,470

NORTH DAKOTA

Clays thousand short tons	W	W	98	$124	[3] 5	[3] $10	85	$119
Coal (lignite) do	2,726	$6,141	2,733	6,135	2,399	5,250	2,637	5,659
Gem stones	(4)	1	(4)	1	(4)	1	(4)	1
Natural gas million cubic feet	20,100	2,533	25,155	3,446	32,798	6,264	34,700	7,634
Natural gas liquids:								
Natural gasoline thousand gallons	W	W	16,872	1,085	20,511	1,339	21,368	1,338
LP gases do	W	W	68,881	2,665	79,653	3,166	84,338	2,960
Petroleum (crude) thousand 42-gallon barrels	23,652	64,333	25,181	69,248	25,030	68,332	25,731	63,813
Sand and gravel thousand short tons	9,395	7,507	9,615	7,122	9,529	9,193	10,520	10,142
Stone do	40	40	19	19	132	132	31	56
Uranium ore short tons			W	W	5,567	141	W	W
Value of items that cannot be disclosed: Clays (bentonite 1963, miscellaneous clay 1963), peat (1963–64), salt, and values indicated by symbol W	XX	4,370	XX	774	XX	875	XX	1,144
Total	XX	84,925	XX	90,619	XX	[r] 94,703	XX	92,866

OHIO

Cement:								
Portland thousand 376-pound barrels	15,303	$53,251	15,353	$51,006	16,218	$53,244	15,553	$50,647
Masonry thousand 280-pound barrels	846	2,604	946	2,793	1,023	3,084	1,068	3,127
Clays thousand short tons	4,923	13,790	4,751	12,979	4,841	13,959	5,005	14,426
Coal (bituminous) do	32,226	121,343	34,125	127,051	36,790	136,113	37,310	137,776
Gem stones	(4)	4	(4)	3	(4)	3	(4)	3
Lime thousand short tons	3,048	41,266	3,102	43,792	3,207	45,957	3,664	53,308
Natural gas million cubic feet	36,423	9,069	36,747	9,407	36,817	8,909	37,309	8,880
Peat short tons	9,113	123	7,383	106	6,910	109	6,363	83
Petroleum (crude) thousand 42-gallon barrels	5,639	17,425	5,835	18,089	6,039	19,023	15,859	46,420
Salt thousand short tons	3,465	25,037	4,187	28,706	4,245	29,682	4,537	31,092
Sand and gravel do	33,688	41,272	35,204	43,333	37,790	44,368	37,771	45,567
Stone do	33,652	55,701	34,470	57,202	37,537	62,787	[5] 37,715	[5] 61,814
Value of items that cannot be disclosed: Abrasive stones, gypsum, stone (calcareous marl 1964)	XX	1,566	XX	1,588	XX	1,742	XX	1,794
Total	XX	382,451	XX	396,055	XX	[r] 418,980	XX	454,937

See footnotes at end of table.

TABLE 5.—Mineral production [1] in the United States, by States—Continued

Mineral	1961		1962		1963		1964	
	Quantity	Value (thousands)	Quantity	Value (thousands)	Quantity	Value (thousands)	Quantity	Value (thousands)
OKLAHOMA								
Clays [3] thousand short tons	792	$801	737	$756	898	$911	835	$854
Coal (bituminous) do	1,032	6,784	1,048	6,978	1,008	5,667	1,028	5,474
Gypsum do	W	W	509	1,668	531	1,462	694	1,899
Helium thousand cubic feet	313,244	5,872	284,214	9,917	237,201	8,302	230,673	8,073
Lead (recoverable content of ores, etc.) short tons	980	202	2,710	499	3,192	689	2,781	729
Natural gas million cubic feet	892,697	108,016	1,060,717	135,772	1,233,883	160,405	1,323,390	166,747
Natural gas liquids:								
Natural gasoline and cycle products thousand gallons	521,237	33,358	552,795	35,764	555,467	35,131	554,053	34,011
LP gases do	817,082	30,141	838,903	25,223	810,894	28,981	880,804	28,055
Petroleum (crude) thousand 42-gallon barrels	193,081	561,866	202,732	591,977	201,962	587,709	202,524	587,320
Salt thousand short tons	3	19	5	25	4	26	6	41
Sand and gravel do	5,310	5,513	4,436	4,736	5,420	6,116	6,680	7,003
Stone do	14,981	16,561	14,666	18,819	13,817	16,160	13,987	15,087
Zinc (recoverable content of ores, etc.) short tons	3,148	724	10,013	2,303	13,245	3,046	12,159	3,307
Value of items that cannot be disclosed: Clay (bentonite), cement, gem stones (1961–62), lime, pumice, tripoli, and values indicated by symbol W	XX	21,920	XX	20,853	XX	22,929	XX	22,670
Total	XX	791,777	XX	855,290	XX	[r] 877,534	XX	881,270
OREGON								
Clays thousand short tons	294	$357	249	$305	279	$330	196	$262
Copper (recoverable content of ores, etc.) short tons	W	W	W	W	W	W	15	10
Diatomite do	----------	----------	50	2	150	3	W	W
Gold (recoverable content of ores, etc.) troy ounces	1,054	37	822	29	1,809	63	661	23
Lime thousand short tons	82	1,702	78	1,514	87	1,835	95	1,918
Mercury 76-pound flasks	138	27	W	W	W	W	126	40
Nickel (content of ore and concentrate) short tons	12,860	W	13,110	W	13,394	W	15,420	W
Perlite do	----------	----------	3	(6)	----------	----------	5	(6)
Pumice thousand short tons	203	461	W	W	422	664	566	909
Sand and gravel do	12,299	13,680	14,869	14,556	15,715	18,850	18,253	25,158
Silver (recoverable content of ores, etc.) thousand troy ounces	2	2	6	7	58	74	14	19
Stone thousand short tons	17,455	21,202	18,258	20,977	19,692	24,197	16,120	19,296
Tungsten concentrate short tons, 60-percent WO_3 basis	----------	----------	----------	----------	----------	----------	1	1
Uranium ore short tons	2,160	66	2,722	112	1,763	45	27	2

Zinc (recoverable content of ores, etc.)....do....	3	1			3	1	W	W
Value of items that cannot be disclosed: Asbestos (1961), cement, gem stones, iron ore (pigment material 1961, 1963), lead (1961, 1963), vanadium (1964), and values indicated by symbol W....	XX	15,557	XX	14,956	XX	16,630	XX	16,631
Total....	XX	53,092	XX	52,458	XX	62,692	XX	64,269

PENNSYLVANIA

Cement:								
Portland....thousand 376-pound barrels..	36,635	$124,506	38,463	$127,969	38,316	$118,203	37,663	$113,409
Masonry....thousand 280-pound barrels..	2,678	7,232	2,565	7,105	2,510	6,611	2,818	7,594
Clays [3]....thousand short tons..	2,999	14,402	2,893	12,815	3,191	14,717	3,187	15,814
Coal:								
Anthracite....do....	17,446	140,338	16,894	134,094	18,267	153,503	17,184	148,648
Bituminous....do....	62,652	323,758	65,315	331,298	71,501	350,085	76,531	388,218
Copper (recoverable content of ores, etc.)....short tons..	W	W	W	W	4,434	2,731	3,614	2,356
Gem stones....	(4)	5	(4)	4	(4)	4	(4)	4
Lime....thousand short tons..	1,093	16,428	1,104	16,647	1,188	17,548	1,440	20,656
Natural gas....million cubic feet..	100,427	29,526	90,053	24,494	92,657	24,091	82,166	22,349
Natural gas liquids:								
Natural gasoline....thousand gallons..	1,272	74	1,350	75	1,311	78	1,138	64
LP gases....do....	1,453	115	1,521	112	1,721	118	1,481	100
Peat....short tons..	27,993	291	32,936	369	33,952	339	39,500	397
Petroleum (crude)....thousand 42-gallon barrels..	5,643	26,579	5,302	24,230	5,083	23,178	5,113	22,088
Sand and gravel....thousand short tons..	12,594	19,766	14,419	23,587	14,066	23,539	16,199	26,414
Stone....do....	41,834	71,344	48,144	82,087	49,536	83,450	52,829	91,075
Zinc (recoverable content of ores, etc.) [10]....short tons..	23,428	5,408	24,308	5,652	27,389	6,572	30,754	8,345
Value of items that cannot be disclosed: Clays (kaolin), cobalt, gold, graphite (1961), iron ore, scrap mica, pyrites, pyrophyllite, silver, tripoli, and values indicated by symbol W....	XX	25,355	XX	32,966	XX	32,644	XX	34,519
Total....	XX	805,127	XX	823,504	XX	[r] 857,411	XX	902,050

RHODE ISLAND

Gem stones....	(4)	W	(4)	W	(4)	$1	(4)	W
Sand and gravel....thousand short tons..	1,726	$1,666	2,346	$1,890	1,750	1,838	1,647	$1,613
Stone....do....	W	W	[5] 304	[5] 483	442	968	450	935
Value of items that cannot be disclosed: Nonmetals and values indicated by symbol W....	XX	1,413	XX	621	XX		XX	1
Total....	XX	3,079	XX	2,994	XX	2,807	XX	2,549

See footnotes at end of table.

TABLE 5.—Mineral production[1] in the United States, by States—Continued

Mineral	1961		1962		1963		1964	
	Quantity	Value (thousands)	Quantity	Value (thousands)	Quantity	Value (thousands)	Quantity	Value (thousands)
SOUTH CAROLINA								
Clays thousand short tons	1,346	$6,169	1,518	$7,165	1,491	$7,589	1,743	$8,309
Mica (sheet) pounds	12	(6)	-------	-------	-------	-------	-------	-------
Sand and gravel thousand short tons	2,904	3,067	3,318	3,670	4,051	4,750	4,622	5,262
Stone do	6,752	9,827	6,382	10,066	7,262	10,926	[5] 6,109	[5] 9,176
Value of items that cannot be disclosed: Barite, cement, feldspar, gem stones (1962–63), kyanite, scrap mica, peat, pyrites, stone (crushed limestone 1964), and vermiculite	XX	12,311	XX	13,000	XX	13,214	XX	15,966
Total	XX	31,374	XX	33,901	XX	36,479	XX	38,713
SOUTH DAKOTA								
Beryllium concentrate short tons, gross weight	238	$130	144	$77	(6)	(6)	W	W
Cement:								
Portland thousand 376-pound barrels	W	W	2,316	7,369	1,869	$5,909	2,001	$6,873
Masonry thousand 280-pound barrels	W	W	60	197	60	198	57	200
Clays thousand short tons	[3] 249	[3] 249	249	690	[r] 240	[r] $960	245	1,076
Coal (lignite) do	18	75	18	77	16	62	13	63
Copper (recoverable content of ores, etc.) short tons	-------	-------	-------	-------	1	(6)	-------	-------
Feldspar long tons	29,354	186	29,697	191	25,590	157	26,980	180
Gem stones	(4)	18	(4)	20	(4)	20	(4)	20
Gold (recoverable content of ores, etc.) troy ounces	557,855	19,525	577,232	20,203	576,726	20,185	616,913	21,592
Gypsum thousand short tons	22	89	23	93	24	97	19	76
Iron ore (usable) thousand long tons	22	100	34	113	-------	-------	-------	-------
Lead (recoverable content of ores, etc.) short tons	-------	-------	3	1	4	1	-------	-------
Mica:								
Scrap short tons	1,054	32	210	6	W	W	996	32
Sheet pounds	18,086	37	2,085	12	10,000	(6)	-------	-------
Petroleum (crude) thousand 42-gallon barrels	233	W	169	W	215	428	247	495
Sand and gravel thousand short tons	11,324	7,336	15,371	9,207	20,806	16,313	13,770	13,641
Silver (recoverable content of ores, etc.) thousand troy ounces	127	118	113	123	117	150	133	172
Stone thousand short tons	2,806	6,642	2,852	6,533	2,794	7,339	2,118	6,245
Uranium ore short tons	43,588	495	29,452	370	72,088	1,931	110,147	1,551

Value of items that cannot be disclosed: Clays (bentonite 1961), lime, lithium minerals (1962–64), molybdenum (1964), vanadium, and values indicated by symbol W	XX	8,975	XX	505	XX	[r] 366	XX	608
Total	XX	44,007	XX	45,787	XX	[r] 54,116	XX	52,824

TENNESSEE

Barite ……short tons	W	W	13,797	$229	24,082	$404	39,188	$519
Cement:								
Portland ……thousand 376-pound barrels	8,357	$26,964	8,509	27,741	8,283	26,760	8,343	26,791
Masonry ……thousand 280-pound barrels	1,018	2,753	1,089	2,931	1,161	3,079	1,212	3,228
Clays [3] ……thousand short tons	1,040	4,190	1,037	4,597	1,238	5,248	1,310	5,576
Coal (bituminous) ……do	5,860	20,681	6,214	22,555	6,121	22,689	5,990	22,674
Copper (recoverable content of ores, etc.) ……short tons	12,272	7,363	14,298	8,808	13,717	8,450	13,889	9,056
Gem stones	(4)	1	(4)	1	(4)	(6)	---	---
Gold (recoverable content of ores, etc.) ……troy ounces	152	5	158	6	137	5	133	5
Lead (recoverable content of ores, etc.) ……short tons	---	---	51	9	---	---	---	---
Natural gas ……million cubic feet	71	13	75	14	90	17	77	15
Petroleum (crude) ……thousand 42-gallon barrels	17	W	14	W	16	W	10	W
Phosphate rock ……thousand long tons	2,235	18,675	2,418	19,868	2,352	17,876	2,441	18,971
Sand and gravel ……thousand short tons	6,232	8,046	6,075	8,018	7,613	9,443	7,972	10,245
Silver (recoverable content of ores, etc.) thousand troy ounces	83	77	112	122	108	138	91	117
Stone ……thousand short tons	23,940	35,906	24,398	35,614	26,825	38,113	[5] 26,497	[5] 38,239
Zinc (recoverable content of ores, etc.) ……short tons	81,734	18,799	71,548	16,456	95,847	22,045	115,943	31,536
Value of items that cannot be disclosed: Clay (fuller's earth 1961–64), iron ore (1961–63), lime, pyrites, stone (crushed sandstone 1964), and values indicated by symbol W	XX	7,238	XX	7,050	XX	[r] 6,458	XX	6,993
Total	XX	150,711	XX	154,019	XX	[r] 160,725	XX	173,965

See footnotes at end of table.

TABLE 5.—Mineral production [1] in the United States, by States—Continued

Mineral	1961		1962		1963		1964	
	Quantity	Value (thousands)	Quantity	Value (thousands)	Quantity	Value (thousands)	Quantity	Value (thousands)
TEXAS								
Cement:								
Portland............thousand 376-pound barrels..	25,101	$80,808	26,204	$83,162	29,104	$92,734	30,030	$94,492
Masonry............thousand 280-pound barrels..	851	2,529	926	2,774	930	2,858	930	2,805
Clays [3]............thousand short tons..	3,786	5,737	3,744	5,634	4,199	6,849	4,156	6,695
Gem stones............	(4)	150	(4)	150	(4)	150	(4)	140
Gypsum............thousand short tons..	1,074	3,832	1,120	3,956	1,099	3,999	1,131	4,049
Helium............thousand cubic feet..	173,066	3,196	245,623	8,552	264,342	9,252	304,909	10,672
Lime............thousand short tons..	790	8,703	1,046	11,999	1,131	13,026	1,350	17,201
Natural gas............million cubic feet..	5,963,605	733,523	6,080,210	747,866	6,205,034	775,629	6,525,649	809,180
Natural gas liquids:								
Natural gasoline and cycle products thousand gallons..	3,111,427	214,279	3,205,517	233,345	3,320,416	218,975	3,512,460	232,245
LP gases............do....	4,768,222	185,558	5,012,291	189,382	5,366,831	169,695	5,521,236	167,492
Perlite............short tons..	-----	-----	-----	-----	-----	-----	300	3
Petroleum (crude)............thousand 42-gallon barrels..	939,191	2,791,377	943,328	2,818,709	977,835	2,908,380	989,525	2,928,994
Salt............thousand short tons..	4,695	17,682	5,553	19,485	5,965	22,355	6,410	28,797
Sand and gravel............do....	27,398	30,691	30,076	33,097	33,256	36,311	29,155	33,394
Stone............do....	38,316	45,874	38,067	48,988	43,142	54,007	40,240	52,070
Sulfur (Frasch process)............thousand long tons..	2,730	62,720	2,655	57,297	2,550	50,109	3,126	62,232
Talc and soapstone............short tons..	78,214	376	73,635	387	72,658	368	89,334	395
Values of items that cannot be disclosed: Native asphalt, barite, bromine, clay (fuller's earth), coal (lignite), feldspar (1961), graphite, iron ore, magnesium chloride (for metal), magnesium compounds (except for metal), pumice, sodium sulfate, and uranium ore............	XX	50,923	XX	58,774	XX	62,777	XX	82,222
Total............	XX	4,237,958	XX	4,323,557	XX	r 4,427,474	XX	4,533,078
UTAH								
Carbon dioxide, natural............thousand cubic feet..	78,136	$5	81,920	$6	100,895	$7	96,432	$7
Clays............thousand short tons..	143	1,080	174	1,403	[3] 125	[3] 470	[3] 1,127	[3] 330
Coal (bituminous)............do....	5,159	31,126	4,297	23,209	4,360	22,755	4,720	33,184
Copper (recoverable content of ores, etc.)......short tons..	213,534	128,120	218,018	134,299	203,095	125,107	199,588	130,131
Fluorspar............do....	610	18	399	12	247	7	W	W
Gem stones............	(4)	73	(4)	75	(4)	75	(4)	75
Gold (recoverable content of ores, etc.)......troy ounces..	342,988	12,005	311,924	10,917	285,907	10,007	287,674	10,069
Iron ore (usable)......thousand long tons, gross weight..	3,533	25,493	2,630	18,242	1,881	12,900	2,082	14,306
Lead (recoverable content of ores, etc.)......short tons..	40,894	8,424	38,199	7,029	45,028	9,726	40,249	10,545
Lime............thousand short tons..	142	2,626	163	2,759	156	2,668	163	2,917
Natural gas............million cubic feet..	57,175	8,976	74,128	12,454	77,122	14,036	80,175	10,904

Perlite short tons	W	W	929	3	1,313	7	2,003	12
Petroleum (crude) thousand 42-gallon barrels	33,118	91,075	31,029	85,019	33,435	90,943	28,575	74,867
Pumice thousand short tons	60	95	28	46	28	46	W	W
Salt do	249	3,187	311	3,349	325	3,462	371	3,848
Sand and gravel do	18,325	16,979	19,941	20,954	11,709	10,408	10,218	10,405
Silver (recoverable content of ores, etc.) thousand troy ounces	4,798	4,435	4,628	5,022	4,791	6,128	4,552	5,886
Stone thousand short tons	1,808	3,219	2,118	3,865	2,346	4,040	3,105	6,930
Uranium ore short tons	1,098,783	25,734	781,955	23,653	743,792	23,852	761,180	26,385
Vanadium (recoverable in ore and concentrate) do	514	W	525	W	382	W	405	1,214
Zinc (recoverable content of ores, etc.) do	37,239	8,565	34,313	7,892	36,179	8,321	31,428	8,548
Value of items that cannot be disclosed: Asphalt (gilsonite), barite (1961–62), cement, clay (fire clay 1963–64), gypsum, molybdenum, natural gas liquids, phosphate rock, potassium salts, and values indicated by symbol W	XX	45,554	XX	50,382	XX	40,458	XX	40,867
Total	XX	416,789	XX	410,590	XX	r385,423	XX	391,430

VERMONT

Gem stones	(4)	$2	(4)	$2	(4)	W	(4)	W
Peat short tons	-----	-----	-----	-----	-----	-----	286	$4
Sand and gravel thousand short tons	2,232	1,567	1,430	1,076	2,375	$1,410	1,764	1,494
Stone do	2,731	18,715	1,715	19,815	2,159	19,193	2,070	20,652
Value of items that cannot be disclosed: Asbestos, clays, lime, talc, and values indicated by symbol W	XX	4,012	XX	4,237	XX	3,788	XX	3,977
Total	XX	24,296	XX	25,130	XX	24,391	XX	26,127

VIRGINIA

Aplite long tons	97,465	$651	125,156	$912	W	W	W	W
Clays thousand short tons	1,406	1,332	1,464	1,444	1,410	$1,558	1,440	$1,614
Coal (bituminous) do	30,332	126,121	29,474	117,560	30,531	120,972	31,654	123,123
Gem stones	(4)	6	(4)	6	(4)	6	(4)	6
Lead (recoverable content of ores, etc.) short tons	3,733	769	4,059	747	3,500	756	3,857	1,010
Lime thousand short tons	657	7,375	615	7,668	639	8,058	780	9,781
Natural gas million cubic feet	2,466	668	2,499	677	2,085	488	1,609	479
Petroleum (crude) thousand 42-gallon barrels	2	W	3	W	3	W	6	W
Sand and gravel thousand short tons	9,839	14,697	9,745	16,375	10,400	17,752	10,588	13,722
Soapstone short tons	W	W	W	W	3,696	9	3,775	9
Stone thousand short tons	22,934	39,206	25,766	43,121	27,653	45,529	30,407	52,153
Zinc (recoverable content of ores, etc.)[10] short tons	29,163	6,726	26,479	6,141	23,988	5,725	21,004	5,700
Value of items that cannot be disclosed: Cement, feldspar, gypsum, iron ore (pigment materials), kyanite, sheet mica (1961), pyrites (1961–62), salt, titanium concentrate, and values indicated by symbol W	XX	27,747	XX	27,843	XX	r28,211	XX	29,818
Total	XX	225,298	XX	222,494	XX	r229,064	XX	237,415

See footnotes at end of table.

TABLE 5.—Mineral production[1] in the United States, by States—Continued

Mineral	1961		1962		1963		1964	
	Quantity	Value (thousands)	Quantity	Value (thousands)	Quantity	Value (thousands)	Quantity	Value (thousands)
WASHINGTON								
Barite.....short tons	5,100	$42	W	W	----	----	----	----
Clays[3].....thousand short tons	145	138	103	$100	134	$123	128	$119
Coal (bituminous).....do	191	1,381	235	1,630	190	1,380	68	575
Copper (recoverable content of ores, etc.).....short tons	66	40	41	25	W	W	35	23
Lead (recoverable content of ores, etc.).....do	8,053	1,659	6,033	1,110	5,374	1,161	5,731	1,502
Peat.....do	57,393	363	41,962	288	37,248	188	35,609	170
Pumice.....thousand short tons	W	W	10	130	W	W	W	W
Sand and gravel.....do	18,994	16,145	19,580	18,145	22,760	20,490	31,920	25,971
Stone.....do	11,464	14,758	12,749	18,180	12,934	16,346	10,276	14,871
Talc and soapstone.....short tons	2,927	23	2,835	11	2,969	18	2,680	18
Uranium ore.....do	175,327	3,582	110,948	2,050	117,286	2,545	147,005	3,601
Zinc (recoverable content of ores, etc.).....do	20,217	4,650	21,644	4,978	22,270	5,122	24,296	6,609
Value of items that cannot be disclosed: Abrasive stones (1961–63), carbon dioxide, cement, clays (fire clay, bentonite 1961), diatomite, epsom salts (1961–63), gem stones, gold, gypsum (1961–62), lime (1963–64), magnesite, olivine, petroleum (1961), silver, tungsten (1961), and values indicated by symbol W	XX	23,667	XX	21,827	XX	24,057	XX	27,518
Total	XX	66,448	XX	68,474	XX	71,430	XX	80,977
WEST VIRGINIA								
Clays.....thousand short tons	475	$2,193	447	$2,086	414	$2,044	[3] 261	[3] $309
Coal (bituminous).....do	113,070	558,525	118,499	578,293	132,568	634,794	141,409	693,572
Natural gas.....million cubic feet	210,556	57,692	210,698	57,942	210,223	55,919	203,872	50,968
Natural gas liquids:								
Natural gasoline.....thousand gallons	34,095	2,296	32,921	2,216	W	W	W	W
LP gases.....do	342,646	17,826	344,969	17,475	W	W	W	W
Petroleum (crude).....thousand 42-gallon barrels	2,760	11,426	3,470	13,880	3,350	13,367	3,370	12,975
Salt.....thousand short tons	899	3,510	1,042	4,635	W	W	1,033	3,666
Sand and gravel.....do	4,882	10,152	5,202	10,942	4,808	10,578	5,472	11,555
Stone[5].....do	7,628	13,244	7,506	13,242	9,452	14,489	7,481	13,105
Value of items that cannot be disclosed: Calcium-magnesium chloride, cement, clay (fire clay 1964), gem stones, lime, stone (dimension sandstone) and values indicated by symbol W	XX	13,385	XX	14,753	XX	37,051	XX	36,541
Total	XX	690,250	XX	715,464	XX	[r] 768,242	XX	822,691

WISCONSIN

Abrasive stones……short tons	[11] 560	[11] $17	[11] 569	[11] $17	[12] 561	[12] $21	W	W
Clays……thousand short tons	126	130	137	156	111	140	119	$147
Iron ore (usable)……thousand long tons, gross weight	1,122	W	1,045	W	938	W	524	W
Lead (recoverable content of ores, etc.)……short tons	680	140	1,394	256	1,116	241	1,742	456
Peat……do	W	W	W	W	2,667	136	3,261	136
Sand and gravel……thousand short tons	39,978	28,457	33,649	24,408	[r] 35,363	[r] 24,863	34,348	24,695
Stone……do	13,418	19,686	13,392	19,709	13,583	18,744	13,901	20,232
Zinc (recoverable content of ores, etc.)……short tons	13,865	3,189	13,292	3,057	15,114	3,476	26,278	7,148
Value of items that cannot be disclosed: Abrasive stones (tube-mill liners, 1963), cement, gem stones, lime, and values indicated by symbol W	XX	21,892	XX	20,686	XX	19,220	XX	17,193
Total	XX	73,511	XX	68,289	XX	[r] 66,841	XX	70,007

WYOMING

Beryllium concentrate……short tons, gross weight	2	$1	1	(6)	(6)	(6)	W	W
Clays……thousand short tons	[3] 859	[3] 10,301	1,141	$11,138	[r] 1,187	[r] $12,385	1,271	$12,816
Coal (bituminous)……do	2,529	8,573	2,569	8,198	3,124	9,922	3,101	9,774
Copper (recoverable content of ores, etc.)……short tons	1	1	----	----	----	----	5	3
Gem stones	(4)	83	(4)	85	(4)	110	(4)	120
Gold (recoverable content of ores, etc.)……troy ounces	1	(6)	----	----	4	(6)	6	(6)
Iron ore (usable)……thousand long tons, gross weight	W	W	739	6,441	1,604	17,504	2,056	24,543
Natural gas……million cubic feet	194,674	24,334	204,996	29,929	209,060	29,687	232,878	29,808
Natural gas liquids:								
Natural gasoline……thousand gallons	76,349	4,705	78,780	4,935	86,014	5,523	86,803	5,607
LP gases……do	132,831	5,451	149,438	5,762	150,437	6,203	152,982	6,433
Petroleum (crude)……thousand 42-gallon barrels	141,937	354,843	135,847	338,259	144,407	361,018	138,752	351,043
Pumice……thousand short tons	20	20	42	41	W	W	W	W
Sand and gravel……do	6,669	5,356	7,769	8,104	7,901	7,874	5,632	5,936
Stone……do	2,594	3,315	1,755	3,054	1,940	2,991	2,154	3,671
Uranium ore……short tons	1,521,064	28,218	1,301,784	25,715	[r] 1,173,420	[r] 23,849	1,490,353	27,911
Vanadium (recoverable in ore and concentrate)……do	W	W	W	442	W	435	W	359
Value of items that cannot be disclosed: Cement, clays (fire clay 1961, miscellaneous clay 1961), gypsum, lime, sheet mica (1961), phosphate rock, silver (1961, 1964), sodium carbonates and sulfates, vermiculite (1961–63), and values indicated by symbol W	XX	21,046	XX	20,467	XX	24,736	XX	26,822
Total	XX	466,247	XX	462,570	XX	[r] 502,237	XX	504,846

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[r] Revised. W Withheld to avoid disclosing individual company confidential data.
XX Not applicable.

[1] Production as measured by mine shipments, sales, or marketable production (including consumption by producers).

[2] Excludes certain cement, included with "Value of items that cannot be disclosed."

[3] Excludes certain clays, included with "Value of items that cannot be disclosed."

[4] Weight not recorded.

[5] Excludes certain stone, included with "Value of items that cannot be disclosed."

[6] Less than ½ unit.

[7] Includes 805 tons of low-grade beryllium ore in 1961, 760 tons in 1962, and 750 tons in 1963.

[8] Excludes salt in brine, included with "Value of items that cannot be disclosed."

[9] Excludes quantity consumed by American Chrome Co.

[10] Recoverable zinc valued at the yearly average price of Prime Western slab zinc, East St. Louis market. Represents value established after transportation, smelting, and manufacturing charges have been added to the value of ore at mine.

[11] Grinding pebbles and tube-mill liners.

[12] Grinding pebbles; tube-mill liners included with "Value of items that cannot be disclosed."

TABLE 6.—Mineral production [1] in the Canal Zone and islands administered by the United States [2]

Area and mineral	1961		1962		1963		1964	
	Quantity	Value (thousands)	Quantity	Value (thousands)	Quantity	Value (thousands)	Quantity	Value (thousands)
American Samoa:								
Pumice thousand short tons	------	------	50	$108	------	------	------	------
Sand and gravel do	------	------	3	4	77	$193	22	$20
Stone do	362	$286	1,103	1,788	944	2,351	157	234
Total	XX	286	XX	1,900	XX	2,544	XX	254
Canal Zone:								
Sand and gravel thousand short tons	75	73	70	77	84	87	84	82
Stone (crushed) do	163	271	207	359	162	281	153	349
Total	XX	344	XX	436	XX	368	XX	431
Canton: Stone (crushed) thousand short tons	------	------	(3)	(3)	2	6	------	------
Guam:								
Sand and gravel do	38	49	------	------	------	------	------	------
Stone do	292	591	82	123	307	439	469	868
Total	XX	640	XX	123	XX	439	XX	868
Johnston:								
Sand and gravel thousand short tons	1	1	------	------	------	------	------	------
Stone do	1	2	------	------	------	------	------	------
Total	XX	3	------	------	------	------	------	------
Midway: Stone (crushed) thousand short tons	11	34	------	------	------	------	------	------
Virgin Islands: Stone (crushed) do	20	75	21	82	66	329	69	342
Wake: Stone (crushed) do	24	62	5	41	9	51	2	5

XX Not applicable.

[1] Production as measured by mine shipments, sales, or marketable production (including consumption by producers).

[2] Production data for Canton and Wake furnished by U.S. Department of Commerce Civil Aeronautics Administration; Midway and Johnston, by U.S. Department of the Navy; Guam, by the Government of Guam; American Samoa, by the Government of American Samoa.

[3] Less than ½ unit.

TABLE 7.—Mineral production [1] in the Commonwealth of Puerto Rico

Mineral	1961		1962		1963		1964	
	Quantity	Value (thousands)	Quantity	Value (thousands)	Quantity	Value (thousands)	Quantity	Value (thousands)
Cement......thousand 376-pound barrels..	5,931	$16,946	6,347	$20,018	7,217	$22,090	7,926	$23,879
Clays......thousand short tons..	184	112	219	131	200	158	341	271
Lime......do....	1	15	1	14	4	103	18	574
Salt......do....	----------	----------	----------	----------	8	131	5	74
Sand and gravel......do....	11,370	10,385	7,378	9,793	7,616	10,407	7,816	11,492
Stone......do....	5,049	7,284	5,589	8,551	5,334	8,237	5,504	8,586
Total......	XX	34,742	XX	38,507	XX	41,126	XX	44,876

XX Not applicable.

[1] Production as measured by mine shipments, sales, or marketable production (including consumption by producers).

TABLE 8.—U.S. imports for consumption of principal minerals and products

Mineral	1963		1964	
	Quantity	Value (thousands)	Quantity	Value (thousands)
Metals:				
Aluminum:				
Metal...short tons	r 415,600	r $163,414	394,563	$163,419
Scrap...do	9,306	2,307	8,152	2,038
Plates, sheets, bars, etc...do	r 41,468	r 25,360	50,542	30,366
Antimony:				
Ore (antimony content)...do	9,784	2,675	10,676	3,294
Needle or liquated...do	22	11	31	21
Metal...do	5,717	2,968	3,307	2,481
Oxide...do	2,089	1,038	3,131	3,022
Arsenic: White (As_2O_3 content)...do	14,559	1,058	18,185	1,383
Bauxite: Crude...thousand long tons	r 9,212	r 114,546	10,262	128,787
Beryllium ore...short tons	6,243	1,672	5,425	1,372
Bismuth (general imports)...pounds	1,123,466	2,082	1,238,252	2,372
Boron carbide...do	13,468	39	4,845	19
Cadmium:				
Metal...thousand pounds	991	2,064	1,104	2,870
Flue dust (cadmium content)...do	r 1,104	r 863	1,272	1,545
Calcium:				
Metal...pounds	26,343	32	42,439	42
Chloride...short tons	2,234	67	2,718	92
Chromate:				
Ore and concentrate (Cr_2O_3 content) do	605,349	20,135	645,693	22,713
Ferrochrome (chromium content)...do	19,945	6,807	17,696	5,783
Metal...do	860	1,308	732	1,109
Cobalt:				
Metal...thousand pounds	10,322	14,677	11,333	16,526
Oxide (gross weight)...do	468	451	1,514	1,422
Salts and compounds (gross weight) do	94	45	94	43
Columbium ore...pounds	5,909,512	3,144	4,600,800	2,277
Copper (copper content):				
Ore and concentrates...short tons	r 6,490	r 3,714	42,936	19,845
Regulus, black, coarse...do	r 2,756	r 1,647	107	675
Unrefined, black, blister...do	r 21,831	r 13,109	121,365	73,300
Refined in ingots, etc...do	r 122,147	r 70,818	110,273	65,652
Old and scrap...do	r 2,130	r 1,219	5,195	3,118
Old brass and clippings...do	945	558	641	415
Ferroalloys: Ferrosilicon (silicon content) do	2,376	744	3,044	908
Gold:				
Ore and base bullion...troy ounces	313,280	10,583	314,674	10,988
Bullion...do	967,339	33,831	854,211	29,900
Iron ore:				
Ore...thousand long tons	33,263	323,158	42,408	421,288
Pyrites cinder...long tons	3,511	48	8,635	49
Iron and steel:				
Pig iron...short tons	645,334	28,937	736,471	31,591
Iron and steel products (major):				
Iron products...short tons	r 57,040	r 10,332	46,055	11,242
Steel products...do	r 5,580,447	r 665,026	6,581,845	814,101
Scrap...do	195,383	5,701	259,178	7,781
Tinplate...do	21,824	403	22,561	472
Lead:				
Ore, flue dust, matte (lead content)...do	r 135,445	r 21,534	128,067	21,789
Base bullion (lead content)...do	3,758	1,792	7,043	2,058
Pigs and bars (lead content)...do	220,398	r 40,126	211,140	45,790
Reclaimed, scrap, etc. (lead content) do	15,405	2,009	1,907	350
Sheets, pipe, and shot...do	2,429	513	1,523	369
Babbitt metal and solder (lead content) short tons	1,246	3,207	1,619	5,785
Type metal and antimonial lead (lead content)...short tons	3,196	621	(1)	(1)
Manufactures...do	2,295	792	2,276	713
Magnesium:				
Metallic and scrap...short tons	r 1,850	r 733	2,227	890
Alloys (magnesium content)...do	r 485	r 660	474	710
Sheets, tubing, ribbons, wire and other forms (magnesium content)...short tons	18	112	40	70
Manganese:				
Ore (35 percent or more manganese) (manganese content)...short tons	1,124,109	67,406	1,430,431	76,977
Ferromanganese (manganese content) short tons	115,377	16,974	162,075	25,811
Mercury:				
Compounds...pounds	14,899	37	8,625	30
Metal...76-pound flasks	42,872	6,766	41,153	8,775

See footnotes at end of table.

TABLE 8.—U.S. imports for consumption of principal minerals and products—Continued

Mineral	1963		1964	
	Quantity	Value (thousands)	Quantity	Value (thousands)
Metals—Continued				
Minor metals: Selenium and salts.....pounds	[r] 339,134	[r] $1,534	292,938	$1,289
Nickel:				
Ore and matte.....short tons	34	3	-----	-----
Pigs, ingots, shot, cathodes.....do	108,127	161,804	104,627	155,973
Scrap.....do	703	520	1,343	1,256
Oxide.....do	12,887	13,753	16,862	17,504
Platinum group:				
Unrefined materials:				
Grains and nuggets, including crude, dust, and residues.....troy ounces	[r] 51,552	[r] 3,757	35,916	3,341
Sponge and scrap.....do	7,647	560	5,127	487
Osmiridium.....do	-----	-----	935	35
Refined metal:				
Platinum.....troy ounces	[r] 382,596	[r] 28,969	578,652	24,366
Palladium.....do	[r] 505,449	11,088	477,198	13,300
Iridium.....do	[r] 13,216	970	6,615	489
Osmium.....do	2,091	50	1,399	113
Rhodium.....do	[r] 36,861	[r] 4,851	55,804	7,955
Ruthenium.....do	[r] 4,196	[r] 181	10,356	404
Radium:				
Radium salts.....milligrams	44,660	304	(1)	(1)
Radioactive substitutes.....	(2)	1,081	(2)	1,869
Rare earths: Ferrocerium and other cerium alloys.....pounds	16,430	49	9,621	48
Silver:				
Ore and base bullion thousand troy ounces	41,660	47,708	43,146	54,235
Bullion.....do	17,402	19,573	8,528	10,159
Tantalum: Ore.....pounds	944,459	2,411	980,702	1,606
Tin:				
Ore (tin content).....long tons	[3] 793	3,077	[4] 5,190	11,539
Blocks, pigs, grains, etc.....do	[r] 43,283	[r] 107,065	31,582	99,378
Dross, skimmings, scrap, residues, and tin alloys, n.s.p.f.....long tons	[r] 2,683	[r] 1,703	1,210	714
Tinfoil, powder, flitters, etc.....	(2)	731	(2)	300
Titanium:				
Ilmenite.....short tons	200,880	5,088	119,819	3,413
Rutile.....do	71,990	4,921	110,981	7,724
Metal.....pounds	[r] 2,935,825	2,535	4,111,285	3,711
Ferrotitanium.....do	82,113	35	55,450	19
Compounds and mixtures.....do	[r] 51,183,772	[r] 9,470	81,794,801	15,322
Tungsten: (tungsten content)				
Ore and concentrate.....thousand pounds	3,060	1,579	3,148	2,008
Metal.....pounds	[r] 147,837	274	65,418	131
Ferrotungsten.....thousand pounds	882	609	195	136
Other alloys.....pounds	41,556	40	29,048	27
Zinc:				
Ore (zinc content).....short tons	371,919	30,757	311,435	35,831
Blocks, pigs, and slabs.....do	132,332	27,942	134,118	31,898
Sheets.....do	1,532	413	1,774	527
Old, dross, and skimmings.....do	2,876	446	3,775	652
Dust.....do	2,608	589	3,269	797
Manufacturers.....	(2)	979	(2)	966
Zirconium: Ore, including zirconium sand short tons	52,543	1,716	44,413	1,184
Nonmetals:				
Abrasives: Diamonds (industrial).....carats	[r] 11,846,153	[r] 49,884	14,374,281	60,051
Asbestos.....short tons	667,860	61,739	739,361	72,973
Barite:				
Crude and ground.....short tons	[r] 578,394	4,643	601,010	4,837
Witherite.....do	2,690	114	2,407	98
Chemicals.....do	[r] 4,647	543	5,190	529
Bromine.....pounds	374,012	168	[5] 897	[5] 3
Cement.....376-pound barrels	4,030,046	10,202	3,633,069	9,228
Clays:				
Raw.....short tons	123,456	2,344	133,140	2,525
Manufactured.....do	2,029	61	3,852	113
Cryolite.....do	26,915	1,808	24,264	1,765
Feldspar: Crude.....long tons	68	2	10	1
Fluorspar.....short tons	[r] 559,653	[r] 14,192	687,933	16,882
Gem stones:				
Diamonds.....carats	2,767,261	223,847	2,644,750	258,534
Emeralds.....do	190,933	2,081	180,069	3,218
Other.....	(2)	29,864	(2)	36,634
Graphite.....short tons	52,184	2,000	47,195	1,944

See footnotes at end of table.

TABLE 8.—U.S. imports for consumption of principal minerals and products—Continued

Mineral	1963		1964	
	Quantity	Value (thousands)	Quantity	Value (thousands)
Nonmetals—Continued				
Gypsum:				
Crude, ground, calcined...short tons	5,490,524	$10,949	6,259,066	$13,358
Manufactures	(2)	1,408	(2)	1,329
Iodine, crude...thousand pounds	3,336	2,958	2,592	2,369
Kyanite...short tons	2,624	119	2,386	104
Lime:				
Hydrated...short tons	692	12	843	10
Other...do	90,676	1,005	93,420	1,112
Dead-burned dolomite...do	9,389	455	28,876	1,165
Magnesium:				
Magnesite...short tons	96,562	5,093	69,480	3,673
Compounds...do	13,552	496	12,591	556
Mica:				
Uncut sheet and punch...pounds	1,133,521	1,615	2,267,681	2,434
Scrap...short tons	8,150	132	2,733	71
Manufactures...do	4,353	5,950	4,433	4,566
Mineral-earth pigments: Iron oxide pigments:				
Natural...short tons	2,877	137	2,902	136
Synthetic...do	7,215	1,150	8,829	1,426
Ocher, crude and refined...do	144	8	191	18
Siennas, crude and refined...do	610	62	726	97
Umber, crude and refined...do	2,641	95	3,412	118
Vandyke brown...do	217	18	259	21
Nitrogen compounds (major), including urea short tons	[r] 1,532,314	[r] 56,316	1,536,631	65,838
Phosphate, crude...long tons	160,708	3,651	155,819	3,329
Phosphatic fertilizers...do	64,144	3,302	70,512	4,010
Pigments and salts:				
Lead pigments and compounds short tons	26,295	4,400	24,250	5,174
Zinc pigments and compounds...do	[r] 16,502	[r] 2,954	12,430	2,389
Potash...do	1,041,376	31,137	1,259,134	36,044
Pumice:				
Crude or unmanufactured...short tons	7,576	84	5,499	65
Wholly or partly manufactured...do	150,343	375	104,444	356
Manufactures, n.s.p.f.	(2)	47	(2)	20
Quartz crystal (Brazillian pebble)...pounds	712,897	547	783,940	512
Salt...short tons	[r] 1,516,159	[r] 5,112	2,339,877	5,677
Sand and gravel:				
Glass sand...short tons	22,724	69	40,308	128
Other sand and gravel...do	336,547	430	443,213	558
Sodium sulfate...thousand short tons	[r] 160	[r] 3,111	290	5,064
Stone and whiting	(2)	18,978	(2)	22,916
Strontium: Mineral...short tons	16,232	372	21,617	506
Sulfur and pyrites:				
Sulfur:				
Ores and other forms, n.e.s...long tons	1,351,216	23,942	1,462,211	26,100
Pyrites...do	194,171	488	10,202	49
Talc: Unmanufactured...short tons	25,681	1,088	22,714	917
Fuels:				
Carbon black:				
Acetylene...pounds	6,233,224	1,104	6,878,084	1,184
Gas black and carbon black...do	1,261,215	216	1,337,683	225
Coal:				
Anthracite...short tons	[6] 4,625	[6] 44	------------	------------
Bituminous, slack, culm, and lignite do	[r] 267,352	[r] 2,075	293,059	2,289
Briquets...do	4,620	82	11,593	182
Coke...do	152,595	2,047	103,286	1,509
Peat:				
Fertilizer grade...short tons	255,709	12,040	265,585	11,997
Poultry and stable grade...do	5,622	318	4,834	256
Petroleum...thousand 42-gallon barrels	[r] 775,036	1,781,685	827,244	2,171,339

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[r] Revised figure.
[1] No longer separately classified.
[2] Weight not recorded.
[3] Data reported as tin content Jan.-Aug.
[4] Reported by the Bureau of the Census as gross weight, adjusted by the Bureau of Mines to tin content.
[5] Not comparable to 1963.
[6] Effective Sept.1, 1963, data no longer separately classified.

Source: Bureau of the Census.

TABLE 9.—U.S. exports of principal minerals and products

Mineral	1963		1964	
	Quantity	Value (thousands)	Quantity	Value (thousands)
Metals:				
Aluminum:				
Ingots, slabs, crude...short tons	165,340	[r] $70,626	208,622	$92,227
Scrap...do	71,040	21,369	68,615	21,476
Plates, sheets, bars, etc...do	53,363	39,276	69,761	50,982
Castings and forgings...do	1,431	4,017	1,832	4,671
Antimony: Metals and alloys, crude...do	14	12	401	223
Arsenic: Calcium arsenate...pounds	186,577	18	1,537,484	96
Bauxite, including bauxite concentrates long tons	203,196	15,696	293,542	23,300
Aluminum sulfate...short tons	17,576	559	16,511	531
Other aluminum compounds...do	228,076	20,635	240,581	23,334
Beryllium...pounds	100,323	457	170,699	630
Bismuth: Metals and alloys...do	32,293	42	47,958	77
Cadmium...thousand pounds	1,313	3,070	1,439	4,033
Calcium chloride...short tons	36,984	1,527	39,893	1,513
Chrome:				
Ore and concentrates:				
Exports...short tons	9,726	352	6,366	241
Reexports...do	[r] 63,764	[r] 2,505	32,116	1,256
Chromic acid...do	936	553	891	523
Ferrochrome...do	2,354	773	10,032	2,504
Cobalt...pounds	2,405,777	2,403	1,453,107	2,002
Columbium metals, alloys, and other forms pounds	61,163	531	348,107	610
Copper:				
Ore, concentrate, composition metal, and unrefined copper (copper content) short tons	1,210	638	5,395	2,971
Refined copper and semimanufactures short tons	344,960	225,649	381,432	262,741
Other copper manufactures...do	5,811	4,273	4,470	3,668
Copper sulfate or blue vitriol...do	851	[r] 227	1,087	275
Copper base alloys...do	44,494	34,587	80,613	56,705
Ferroalloys:				
Ferrosilicon...pounds	6,260,880	948	11,569,493	1,232
Ferrophosphorus...do	82,722,701	1,302	326,332,849	4,938
Gold:				
Ore and base bullion...troy ounces	30,107	1,140	21,566	755
Bullion, refined...do	5,789,826	202,644	12,056,841	421,989
Iron ore...thousand long tons	[r] 6,812	[r] 76,340	6,963	79,670
Iron and steel:				
Pig iron...short tons	70,154	4,479	176,056	10,275
Iron and steel products (major):				
Semimanufactures...short tons	[r] 1,615,463	[r] 302,553	2,646,436	422,035
Manufactured steel mill products short tons	[r] 1,054,482	[r] 309,642	1,264,427	440,549
Advanced products...do	(1)	[r] 165,433	(1)	206,378
Iron and steel scrap: Ferrous scrap, including rerolling materials...short tons	6,363,617	174,611	7,886,469	243,123
Lead:				
Ore, matte, base bullion (lead content) short tons	4	(2)	19	4
Pigs, bars, anodes...do	1,088	313	10,175	2,813
Scrap...do	2,421	1,034	13,148	2,384
Magnesium:				
Metal and alloys and semimanufactured forms, n.e.c...short tons	[r] 16,174	[r] 9,787	16,811	10,202
Powder...do	33	87	8	29
Manganese:				
Ore and concentrates...do	8,296	926	14,444	1,451
Ferromanganese...do	678	155	3,903	670
Mercury:				
Exports...76-pound flasks	187	46	[3] 188	[3] 52
Reexports...do	[r] 40	[r] 6	196	50
Molybdenum:				
Ore and concentrates (molybdenum content)...pounds	26,545,066	39,360	24,939,780	40,987
Metals and alloys, crude and scrap...do	139,202	179	1,404,502	3,630
Wire...do	30,892	631	30,903	500
Semifabricated forms, n.e.c...do	9,109	110	34,950	290
Powder...do	16,741	58	310,957	1,178
Ferromolybdenum...do	239,034	379	1,745,611	3,328
Nickel:				
Ore...short tons	12	5	8	3
Alloys and scrap (including Monel metal), ingots, bars, sheets, etc...short tons	59,107	27,279	66,108	35,412

See footnotes at end of table.

TABLE 9.—U.S. exports of principal minerals and products—Continued

Mineral	1963		1964	
	Quantity	Value (thousands)	Quantity	Value (thousands)
Metals—Continued				
Nickel—Continued				
Catalysts ---- short tons	905	$1,749	1,002	$2,013
Nickel-chrome electric resistance wire ---- do	189	953	445	1,929
Semifabricated forms, n.e.c ---- do	714	3,199	939	4,754
Platinum:				
Ore, concentrate, metal and alloys in ingots, bars, sheets, anodes, and other forms, including scrap ---- troy ounces	51,236	3,650	125,139	9,842
Palladium, rhodium, iridium, osmiridium, ruthenium, and osmium (metal and alloys including scrap) ---- troy ounces	11,776	507	21,167	1,363
Platinum group manufactures, except jewelry	(1)	2,256	(1)	5,083
Radium metal (radium content) ---- milligrams	311	7	177	2
Rare earths:				
Cerium ore, metal, and alloys ---- pounds	128,612	41	1,637,142	400
Lighter flints ---- do	40,100	182	37,455	139
Silver:				
Ore and base bullion ---- thousand troy ounces	1,298	1,650	2,676	3,460
Bullion, refined ---- do	30,187	38,372	106,718	137,937
Tantalum:				
Ore, metal, and other forms ---- pounds	100,400	861	232,282	1,211
Powder ---- do	14,146	425	32,217	574
Tin:				
Ingots, pigs, bars, etc:				
Exports ---- long tons	1,544	4,225	2,726	9,241
Reexports ---- do	81	207	1,315	6,225
Tin scrap and other tin-bearing material except tinplate scrap ---- long tons	5,862	2,423	4,844	2,151
Tin cans finished or unfinished ---- do	21,595	12,169	23,963	14,244
Titanium:				
Ore and concentrates ---- short tons	1,212	176	2,161	386
Sponge (including iodide titanium) and scrap ---- short tons	1,261	1,232	1,817	1,781
Intermediate mill shapes ---- do	417	2,322	790	3,696
Mill products, n.e.c ---- do	77	1,122	75	1,302
Ferrotitanium ---- do	211	183	541	392
Dioxide and pigments ---- do	26,702	8,051	29,359	8,287
Tungsten: Ore and concentrate:				
Exports ---- do	r 49	r 65	77	145
Reexports ---- do	----	----	150	122
Vanadium ore and concentrate, pentoxide, etc. (vanadium content) ---- pounds	1,071,817	1,641	2,461,193	3,620
Zinc:				
Ore and concentrate (zinc content) ---- short tons	17	6	39	12
Slabs, pigs, or blocks ---- do	33,853	7,506	26,515	7,240
Sheets, plates, strips, or other forms, n.e.c. ---- short tons	3,756	2,742	6,569	3,978
Scrap (zinc content) ---- do	1,794	539	6,448	1,379
Dust ---- do	759	261	1,828	542
Semifabricated forms, n.e.c ---- do	1,532	1,163	5,666	2,451
Zirconium:				
Ore and concentrate ---- short tons	1,418	305	2,500	352
Metals and alloys and other forms ---- pounds	r 298,466	2,500	533,449	3,191
Nonmetals:				
Abrasives:				
Grindstones ---- short tons	41	34	179	48
Diamond dust and powder ---- carats	r 1,110,237	r 3,020	1,892,097	4,097
Diamond grinding wheels ---- do	373,053	2,354	405,328	2,709
Other natural and artificial metallic abrasives and products	(1)	r 30,366	(1)	37,248
Asbestos: Unmanufactured:				
Exports ---- short tons	9,978	1,289	26,819	3,162
Reexports ---- do	66	15	328	37
Boron: Boric acid, borates, crude and refined ---- pounds	677,823,693	27,519	766,200,586	31,289
Bromine, bromides, and bromates ---- do	r 12,407,580	r 2,590	17,036,442	3,437
Cement ---- 376-pound barrels	460,088	2,072	712,678	3,290
Clays:				
Kaolin or china clay ---- short tons	111,717	3,314	151,725	4,671
Fire clay ---- do	264,440	5,184	246,796	5,596
Other clays ---- do	363,191	12,875	449,537	14,706
Cryolite ---- do	3,719	689	3,385	744
Fluorspar ---- do	1,202	157	3,702	158

See footnotes at end of table.

TABLE 9.—U.S. exports of principal minerals and products—Continued

Mineral	1963		1964	
	Quantity	Value (thousands)	Quantity	Value (thousands)
Nonmetals—Continued				
Graphite:				
Amorphous short tons	533	$89	1,326	$194
Crystalline flake, lump or chip do	144	49	229	62
Natural, n.e.c. do	222	51	409	77
Gypsum:				
Crude, crushed, or calcined thousand short tons	17	669	21	829
Manufactures, n.e.c.	(1)	762	(1)	979
Iodine, iodide, iodates thousand pounds	141	327	147	343
Kyanite and allied minerals short tons	5,050	442	6,080	393
Lime do	17,463	565	29,858	777
Mica:				
Unmanufactured pounds	594,427	148	542,516	161
Manufactured:				
Ground or pulverized pounds	7,244,428	413	8,263,497	478
Other do	204,246	831	281,131	946
Mineral-earth pigments: Iron oxide, natural and manufactured short tons	4,189	1,306	5,097	1,817
Nitrogen compounds (major) do	824,295	41,357	1,182,425	67,636
Phosphate rock long tons	[r] 4,624,912	[r] 40,834	5,652,573	52,630
Phosphatic fertilizers (superphosphates) do	601,887	29,220	707,943	33,259
Pigments and compounds (lead and zinc):				
Lead pigments short tons	1,845	620	1,680	608
Zinc pigments do	3,801	963	3,619	899
Lead compounds do	401	135	936	278
Potash:				
Fertilizer short tons	707,039	22,202	1,026,446	32,563
Chemical do	14,703	3,317	22,033	5,024
Quartz crystal (raw)	(1)	525	(1)	558
Radioactive isotopes, etc. curie	146,783	2,548	388,112	2,919
Salt:				
Crude and refined short tons	781,135	4,140	594,318	3,373
Shipments to noncontiguous Territories short tons	10,021	881	13,966	1,174
Sodium and sodium compounds:				
Sodium sulfate short tons	45,163	1,379	43,545	1,320
Sodium carbonate thousand short tons	184	5,722	273	8,368
Stone:				
Limestone, crushed, ground, broken short tons	762,658	1,753	1,369,728	2,079
Marble and other building and monumental cubic feet	452,167	1,669	441,312	2,027
Stone, crushed, ground, broken short tons	110,949	2,095	105,504	2,013
Manufactures of stone	(1)	585	(1)	677
Sulfur:				
Crude long tons	1,603,438	33,531	1,920,392	39,651
Crushed, ground, flowers of do	9,199	1,057	7,700	1,287
Talc:				
Crude and ground short tons	56,483	2,690	73,998	3,316
Manufactures, n.e.c. do	107	88	128	75
Powders-talcum (face and compact)	(1)	1,140	(1)	1,068
Fuels:				
Carbon black thousand pounds	370,928	[r] 35,010	333,907	31,929
Coal:				
Anthracite short tons	[r] 3,357,340	[r] 43,719	1,575,097	22,060
Bituminous do	47,078,435	429,864	47,969,423	441,216
Briquets do	12,380	207	17,857	210
Coke do	451,241	8,318	523,695	10,093
Petroleum:				
Crude thousand 42-gallon barrels	1,697	4,616	1,361	3,806
Gasoline[4] do	6,418	44,720	7,125	50,070
Kerosine do	513	3,405	160	1,240
Distillate oil do	[r] 16,934	56,087	6,507	20,498
Residual oil do	15,281	36,411	19,135	41,853
Lubricating oil do	[r] 17,805	[r] 228,643	17,628	221,896
Asphalt do	656	3,847	614	4,909
Liquefied petroleum gases do	4,597	13,438	5,365	14,836
Wax do	1,455	29,094	1,736	32,849
Coke do	10,763	38,170	13,618	45,491
Petrolatum do	240	6,202	236	6,146
Miscellaneous do	566	[r] 15,442	561	16,223

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[r] Revised.

[1] Weight not recorded.

[2] Less than ½ unit.

[3] Excludes 10,275 pounds of spent catalysts, valued at $12,272 and 171,152 pounds of residues, valued at $17,980.

[4] Includes naphtha, but excludes benzol: 1963 (revised figures)—1,752,372 barrels ($19,473,039); 1964—2,078,183 barrels ($22,336,739).

TABLE 10.—Comparison of world and United States production of principal metals and minerals

Mineral	1963			1964 [p]		
	World	United States		World	United States	
	Thousand short tons (unless otherwise stated)		Percent of world	Thousand short tons (unless otherwise stated)		Percent of world
Fuels:						
Carbon black..thousand pounds..	NA	2,058,916	NA	NA	2,223,216	NA
Coal:						
Bituminous	1,938,849	456,223	24	2,012,093	484,048	24
Lignite	786,321	2,705	(1)	818,165	2,950	(1)
Pennsylvania anthractie	201,500	18,267	9	205,700	17,184	8
Coke (excluding breeze):						
Gashouse [2]	49,960	160	(1)	48,630	203	(1)
Oven and beehive	307,795	54,278	18	326,602	62,145	19
Fuel briquets and packaged fuel	133,900	565	(1)	129,900	368	(1)
Natural gas (marketable) million cubic feet..	NA	14,746,663	NA	NA	15,546,592	NA
Peat	171,200	[3] 579	(1)	183,400	[3] 649	(1)
Petroleum (crude)....thousand 42-gallon barrels..	9,537,420	2,752,723	29	10,327,591	2,805,125	27
Nonmetals:						
Asbestos	3,210	66	2	3,540	101	3
Barite	3,190	803	25	3,370	817	24
Cement [4]....thousand 376-pound barrels..	2,209,950	368,406	17	2,374,109	385,387	16
China clay	NA	3,164	NA	NA	3,331	NA
Corundum	11	------	------	9	------	------
Diamonds.....thousand carats..	36,661	------	------	36,285	------	------
Diatomite	1,690	482	29	1,720	482	28
Feldspar....thousand long tons..	1,690	549	32	1,770	630	36
Fluorspar	2,340	200	9	2,770	217	8
Graphite	780	W	W	600	W	W
Gypsum	49,900	10,388	21	51,530	10,684	21
Lime (sold or used by producers)	NA	14,521	NA	NA	16,089	NA
Magnesite	9,200	528	6	10,000	W	W
Mica (including scrap) thousand pounds..	400,000	218,749	55	410,000	229,701	56
Nitrogen, agricultural [4] [5]	14,200	3,847	27	15,400	4,414	29
Phosphate rock thousand long tons..	50,590	19,855	39	57,910	22,960	40
Potash (K^2O equivalent)	12,100	2,864	24	13,000	2,897	22
Pumice [6]	14,800	2,618	18	14,340	2,776	19
Pyrites......thousand long tons..	19,600	825	4	20,000	847	4
Salt [4]	104,700	30,649	29	108,800	31,628	29
Strontium [6]	17	------	------	23	------	------
Sulfur, elemental thousand long tons..	12,600	5,829	46	13,800	6,250	45
Talc, pyrophyllite, and soapstone	3,330	804	24	3,760	890	24
Vermiculite [6]	327	226	69	343	226	66
Metals, mine basis:						
Antimony (content of ore and concentrate)..........short tons..	61,600	645	1	68,000	632	1
Arsenic, white [6]	52	W	W	58	W	W
Bauxite......thousand long tons..	30,220	1,525	5	33,145	1,601	5
Beryllium concentrate short tons..	7,700	751	10	[7] 5,700	W	W
Bismuth.......thousand pounds..	6,800	W	W	7,200	W	W
Cadmium.....thousand pounds..	26,600	9,990	38	27,900	10,458	37
Chromite	4,355	------	------	4,720	------	------
Cobalt (contained) [6]..short tons..	12,900	W	W	14,500	W	W
Columbium-tantalum concentrates [6].......thousand pounds..	11,060	------	------	10,800	------	------
Copper (content of ore and concentrate)	5,210	1,213	23	5,420	1,247	23
Gold......thousand troy ounces..	44,200	1,469	3	46,100	1,469	3
Iron ore......thousand long tons..	513,661	73,599	14	566,716	84,836	15
Lead (content of ore and concentrate)	2,805	253	9	2,735	286	10
Manganese ore (35 percent or more Mn)	16,138	11	(1)	16,687	26	(1)
Mercury thousand 76-pound flasks..	239	19	8	251	14	6
Molybdenum (content of ore and concentrate).thousand pounds..	90,900	65,011	72	94,400	65,605	69
Nickel (content of ore and concentrate)	395	11	3	427	12	3

See footnotes at end of table.

TABLE 10.—Comparison of world and United States production of principal metals and minerals—Continued

Mineral	1963			1964 [p]		
	World	United States		World	United States	
	Thousand short tons (unless otherwise stated)		Percent of world	Thousand short tons (unless otherwise stated)		Percent of world
Metals, mine basis—Continued						
Platinum groups (Pt, Pd, etc.) thousand troy ounces	1,545	50	3	2,050	40	2
Silver do	250,800	35,000	14	249,500	37,000	15
Tin (content of ore and concentrate) long tons	190,400	W	W	194,200	W	W
Titanium concentrates:						
Ilmenite [6]	2,186	888	41	2,576	1,001	39
Rutile [6]	222	12	5	212	8	4
Tungsten concentrate (60 percent WO_3) short tons	64,600	5,657	9	64,900	9,244	14
Vanadium (content of ore and concentrate) [6] short tons	7,155	3,853	54	7,600	4,362	57
Zinc (content of ore and concentrate)	4,020	529	13	4,395	575	13
Metals, smelter basis:						
Aluminum	6,080	2,313	38	6,730	2,553	38
Copper	5,480	1,297	24	5,750	1,338	23
Iron, pig (including ferroalloys)	310,121	73,853	24	350,092	87,922	25
Lead	2,750	395	14	2,830	449	16
Magnesium short tons	160,000	75,845	47	165,900	79,488	48
Selenium [6] thousand pounds	2,071	928	45	2,102	929	44
Steel ingots and castings	425,470	109,261	26	480,780	127,076	26
Tellurium [6] thousand pounds	318	201	63	279	145	52
Tin long tons	192,000	[8] 1,650	1	189,300	[8] 5,190	3
Uranium oxide (U_3O_8) [6] short tons	31,020	14,218	46	25,590	11,847	46
Zinc	3,830	893	23	4,055	954	24

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[p] Preliminary. NA Not available. W Withheld to avoid disclosing individual company confidential data.

[1] Less than 0.05 percent.

[2] Includes low- and medium-temperature and gashouse coke.

[3] Agricultural use only.

[4] Including Puerto Rico.

[5] Year ended June 30 of year stated (United Nations).

[6] World total exclusive of U.S.S.R.

[7] Not including U.S. output which was very small, but withheld to avoid disclosing individual company confidential data.

[8] U.S. imports of tin concentrates (tin content).

Employment and Injuries in the Metal and Nonmetal Industries

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By Forrest T. Moyer[1]

INJURY experience in the metal and nonmetal mineral industries during 1964 was better in rates of occurrence but worse in severity rates than in 1963. The frequency rate of injuries per million man-hours was improved at metal mills, nonmetal mines, and sand and gravel operations, and was virtually unchanged at metal mines; however, the rate of occurrence of work injuries at nonmetal mills, stone operations, nonferrous reduction and refining plants, and slag plants was higher than in 1963.

The severity rate of injuries during 1964, data for which are presented for the first time in this chapter, was better at metal mills, nonmetal mines, stone operations, and slag plants. However, the severity rate was worse at metal mines, nonmetal mills, sand and gravel plants, and nonferrous smelters.

The average number of men working daily was greater in 1964 in all of the broad industry groups discussed in this chapter. The increased operating activity also is indicated in each group by the gain in man-hours of worktime during 1964.

In addition to the industry classifications included in this chapter, similar employment and injury experience data on the mineral fuels industries are presented in volume II. Corresponding data for broad classifications of mineral industry groups are given by States in volume III.

METAL MINES AND MILLS

The slight worsening in the overall safety record of the metal mining and milling industry for 1964 resulted from the less favorable experience at metal mines. At metal mills, the injury frequency and severity rates were improved over 1963. Activity in both the mining and milling of metallic ores was higher in 1964, and the number of men and the man-hours of worktime increased over those of 1963.

Copper.—The rate of occurrence of injuries at copper mines in 1964 increased to 29.14 per million man-hours. However, the severity rate of 3,551 days lost per million man-hours decreased. The total of 12 fatalities was 2 less than in 1963, but the number of nonfatal injuries increased to 1,045 compared with 908 injuries in 1963. In the milling of copper ores, both the injury frequency and severity rates were more favorable than in 1963.

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The average number of men working daily and the total man-hours of worktime increased substantially in 1964 at both copper mines and mills.

Gold-Silver (Lode and Placer).—Injury experience at gold-silver lode and placer mines and mills was improved in 1964 owing to the lower number of injuries. The severity rate of injuries at mines was reduced sharply as there were two less fatalities than in 1963.

Operating activity at both mines and mills was relatively unchanged from 1963, as measured by the number of men and man-hours worked in each year.

Iron.—In the iron ore mining and milling industry in 1964, the safety record at the mines improved, but it worsened at the mills. The injury-frequency rate at the mines was lowered to 14.98, and the severity rate was reduced to 3,256 days lost per million man-hours. At the mills, both the injury frequency and severity rates were appreciably higher than in 1963, primarily because of the one fatality and the larger number of nonfatal injuries in 1964.

Employment and man-hours worked at iron mines and mills were greater than in 1963.

Lead-Zinc.—The injury-frequency rate at lead-zinc mines was improved in 1964, although the numbers of fatal and nonfatal injuries were greater than in 1963. This improvement resulted from the larger proportional gain in man-hours of exposure. However, the severity rate worsened appreciably owing principally to the total of 19 fatalities in 1964, compared with 6 in the preceding year. At lead-zinc mills, both the frequency and severity rates of injuries showed marked improvement in 1964, and there were fewer fatal and nonfatal injuries than in 1963.

The number of men working at lead-zinc mines increased slightly and at the mills decreased slightly in 1964. However, operating activity, as measured by manhours worked, was appreciably higher at the mines and slightly higher at the mills.

Uranium.—The safety record at uranium mines was worse than in 1963, and both the frequency and severity rates of injuries were appreciably higher. At uranium mills, the injury-frequency rate was improved in 1964, but the severity rate was appreciably higher, owing principally to the one fatality during the year.

Employment at uranium mines and mills continued to decline in 1964. The total man-hours worked at the mines was sharply lower than in 1963, but at the mills slightly more time was worked in 1964.

Miscellaneous Metals.—The injury-frequency rate was improved slightly in 1964 at mines in the miscellaneous metal group. However, the severity rate was appreciably higher owing to the three fatalities in 1964, compared with one in 1963. At milling operations in this group, the rate of occurrence of injuries was less favorable, and the severity rate was only slightly better than the comparable rate in 1963.

TABLE 1.—Employment and injury experience at metal mines in the United States, by industry groups

Industry and year	Men working daily	Average active mine days	Man-days worked (thousands)	Man-hours worked (thousands)	Number of injuries		Injury rates per million man-hours	
					Fatal	Nonfatal	Frequency	Severity
Copper:								
1955–59 (average)	16,397	283	4,647	37,122	22	1,169	32.08	NA
1960	16,077	275	4,421	35,388	17	828	23.88	2,858
1961	15,661	285	4,460	35,790	13	893	25.31	3,847
1962	15,629	280	4,377	35,017	15	908	26.36	4,598
1963	14,547	297	4,326	34,611	14	908	26.64	4,199
1964 [p]	15,400	294	4,544	36,270	12	1,045	29,14	3,551
Gold-silver (lode-placer):								
1955–59 (average)	4,809	234	1,123	9,094	7	514	57.29	NA
1960	4,893	218	1,067	8,616	6	289	34.24	5,849
1961	5,011	213	1,068	8,576	4	365	43.03	5,852
1962	4,361	215	937	7,553	8	268	36.54	7,945
1963	4,823	210	1,015	8,162	6	265	33.20	6,405
1964 [p]	4,900	207	1,002	8,040	4	255	32.21	4,113
Iron:								
1955–59 (average)	24,184	225	5,449	43,694	15	606	14.21	NA
1960	21,170	242	5,131	41,158	16	610	15.21	3,703
1961	17,251	224	3,868	31,027	10	449	14.79	3,014
1962	16,165	234	3,776	30,481	9	453	15.16	2,799
1963	13,353	251	3,357	27,079	10	402	15.21	3,339
1964 [p]	14,500	255	3,709	29,840	12	435	14.98	3,256
Lead-zinc:								
1955–59 (average)	10,087	254	2,562	20,494	16	1,231	60.85	NA
1960	8,137	227	1,845	14,750	12	959	65.83	8,149
1961	7,510	243	1,829	14,628	7	1,167	80.26	6,441
1962	7,150	243	1,735	13,877	9	935	68.03	7,713
1963	7,443	234	1,738	13,901	6	961	69,56	5,076
1964 [p]	7,900	257	2,033	16,580	19	1,040	63.87	10,325
Uranium:[1]								
1960	7,329	233	1,710	13,832	32	862	64.63	16,599
1961	5,965	245	1,461	11,811	11	525	45.38	8,203
1962	5,967	231	1,379	11,175	13	420	38.75	9,059
1963	5,086	199	1,011	8,163	4	348	43.12	4,531
1964 [p]	4,600	197	900	7,300	4	365	50.55	7,804
Miscellaneous:[2]								
1955–59 (average)	8,530	238	2,028	16,324	16	1,010	62.85	NA
1960	2,989	246	736	5,908	1	246	41.81	2,989
1961	2,853	256	730	5,846	5	270	47.04	9,157
1962	3,015	239	720	5,764	7	279	49.62	9,279
1963	2,592	251	650	5,196	1	191	36.95	2,613
1964 [p]	3,600	257	923	7,390	3	195	26.79	3,988
Total:[3]								
1955–59 (average)	64,008	247	15,810	126,727	76	4,529	36.34	NA
1960	60,595	246	14,910	119,653	84	3,794	32.41	5,902
1961	54,251	247	13,416	107,678	50	3,669	34.54	4,885
1962	52,287	247	12,924	103,867	61	3,263	32.00	5,469
1963	47,844	253	12,096	97,111	41	3,075	32.09	4,212
1964 [p]	50,900	258	13,111	105,420	54	3,335	32.15	4,901

[p] Preliminary. NA Not available.

[1] Classed as uranium-vanadium and included with miscellaneous prior to 1960.

[2] Includes uranium prior to 1960.

[3] Data may not add to totals shown because of rounding.

Operating activity at miscellaneous metal mines was higher in 1964, and both employment and man-hours of worktime increased markedly over those of 1963. At mills, however, employment and worktime were lower than in 1963.

Operations in the miscellaneous metals group are those mines and mills working metallic ores such as antimony, bauxite, manganese, mercury, rare earths, titanium, and others not specified earlier in this chapter.

TABLE 2.—Employment and injury experience at metal mills in the United States, by industry groups

Industry and year	Men working daily	Average active mill days	Man-days worked (thousands)	Man-hours worked (thousands)	Number of injuries		Injury rates per million man-hours	
					Fatal	Nonfatal	Frequency	Severity
Copper:								
1955–59 (average)	6,409	304	1,947	15,625	2	179	11.58	NA
1960	5,255	314	1,648	13,188	3	111	8.64	1,574
1961	5,688	317	1,804	14,434	--------	106	7.34	286
1962	5,947	325	1,935	15,482	7	127	8.66	2,940
1963	4,839	320	1,550	12,402	1	91	7.42	1,545
1964 [p]	5,400	314	1,684	13,470	1	90	6.75	878
Gold-silver (lode-placer):								
1955–59 (average)	410	276	113	908	--------	26	28.63	NA
1960	253	286	72	580	--------	2	3.45	60
1961	343	241	83	659	--------	12	18.21	220
1962	347	251	87	702	--------	30	42.74	1,845
1963	335	263	88	708	--------	25	35.31	768
1964 [p]	350	263	91	730	--------	15	20.55	412
Iron:								
1955–59 (average)	5,314	238	1,265	10,179	1	72	7.17	NA
1960	6,413	258	1,653	13,320	--------	79	5.93	543
1961	5,515	266	1,468	11,777	3	65	5.77	1,804
1962	4,868	283	1,376	11,130	3	91	8.45	2,167
1963	4,856	287	1,392	11,189	--------	65	5.81	283
1964 [p]	5,600	292	1,626	12,980	1	95	7.40	724
Lead-zinc:								
1955–59 (average)	2,793	251	702	5,627	1	89	16.00	NA
1960	1,614	258	416	3,336	--------	70	20.98	414
1961	1,322	241	319	2,554	--------	76	29.76	1,688
1962	1,743	254	442	3,539	--------	55	15.54	653
1963	1,356	229	310	2,484	2	65	26.97	7,093
1964 [p]	1,300	263	345	2,760	1	50	18.48	2,852
Uranium:[1]								
1960	2,578	321	826	6,610	1	138	21.03	2,431
1961	2,481	312	775	6,222	--------	95	15.27	1,051
1962	2,219	302	670	5,406	2	87	16.46	2,842
1963	1,796	275	494	3,988	--------	75	18.81	404
1964 [p]	1,700	294	499	4,080	1	60	14.95	1,897
Miscellaneous:[2]								
1955–59 (average)	4,586	293	1,343	10,759	2	241	22.59	NA
1960	6,416	323	2,074	16,605	1	88	5.36	517
1961	5,169	336	1,737	13,907	--------	104	7.48	310
1962	4,859	332	1,613	12,904	2	92	7.28	1,227
1963	4,834	339	1,638	13,103	2	89	6.94	1,134
1964 [p]	4,300	313	1,341	10,740	1	95	8.94	1,116
Total:[3]								
1955–59 (average)	19,512	275	5,370	43,098	6	607	14.22	NA
1960	22,529	297	6,689	53,638	5	488	9.19	1,008
1961	20,518	301	6,186	49,552	3	458	9.30	821
1962	19,983	306	6,123	49,163	14	482	10.09	2,124
1963	18,016	304	5,472	43,874	5	410	9.46	1,298
1964 [p]	18,600	301	5,586	44,760	5	410	9.27	1,097

[p] Preliminary. NA Not available.

[1] Classed as uranium-vanadium and included with miscellaneous metals prior to 1960.

[2] Includes uranium prior to 1960.

[3] Data may not add to totals shown because of rounding.

NONFERROUS REDUCTION AND REFINING PLANTS

The overall injury experience at primary nonferrous reduction plants and refineries was less favorable in 1964. The frequency rate of injuries advanced slightly to 10.75, and the severity rate was sharply higher at 1,103 days lost per million man-hours, compared with 965 in 1963. Both the injury frequency and severity rates were improved only at plants reducing or refining the miscellaneous metals such as antimony, magnesium, titanium, and others. The safety record was worse than in 1963 at lead and zinc smelters and refineries. At plants producing primary copper, the injury-severity rate was improved sharply, but the frequency rate was slightly less favorable than in 1963. At aluminum reduction works, the rate of occurrence of injuries was better, but the severity rate worsened owing to the three fatalities in 1964.

Operating activity at the primary nonferrous smelting and refining plants in general was higher in 1964. Both the number of men and man-hours worked at all plants was higher than in 1963.

TABLE 3.—Employment and injury experience at primary nonferrous reduction and refinery plants in the United States, by industry groups

Industry and year	Men working daily	Average active smelter days	Man-days worked (thousands)	Man-hours worked (thousands)	Number of injuries		Injury rates per million man-hours	
					Fatal	Nonfatal	Frequency	Severity
Copper:								
1955–59 (average)	11, 543	307	3, 544	28, 445	4	380	13. 50	NA
1960	11, 805	313	3, 693	29, 445	3	370	12. 67	1, 083
1961	11, 414	329	3, 750	29, 999	3	420	14. 10	1, 398
1962	10, 954	328	3, 590	28, 697	5	360	12. 72	1, 563
1963	10, 289	334	3, 443	27, 579	2	339	12. 36	1, 020
1964 [p]	10, 500	323	3, 385	27, 100	1	355	13. 14	745
Lead:								
1955–59 (average)	3, 358	289	969	7, 752	2	132	17. 29	NA
1960	2, 782	267	742	5, 939	1	103	17. 51	1, 819
1961	2, 493	300	747	5, 973	--------	116	19. 41	995
1962	2, 493	289	720	5, 760	2	82	14. 58	2, 443
1963	2, 581	277	715	5, 720	1	61	10. 84	2, 057
1964 [p]	2, 300	330	769	6, 160	1	85	13. 96	2, 833
Zinc:								
1955–59 (average)	8, 503	328	2, 793	22, 269	1	546	24. 56	NA
1960	7, 392	293	2, 169	17, 354	2	279	16. 19	1, 272
1961	6, 518	328	2, 138	17, 107	2	360	21. 16	1, 740
1962	6, 588	328	2, 158	17, 246	--------	277	16. 06	399
1963	6, 108	346	2, 114	16, 909	3	261	15. 61	1, 498
1964 [p]	6, 600	337	2, 228	17, 640	3	325	18. 59	1, 737
Aluminum: [1]								
1960	12, 630	346	4, 365	34, 920	1	214	6. 16	684
1961	13, 408	326	4, 371	34, 966	1	331	9. 50	854
1962	13, 184	336	4, 433	35, 453	3	269	7. 67	1, 067
1963	12, 666	359	4, 522	36, 178	--------	239	6. 61	410
1964 [p]	13, 800	334	4, 625	37, 750	3	200	5. 38	874
Miscellaneous: [2]								
1955–59 (average)	16, 363	355	5, 815	46, 355	2	439	9. 51	NA
1960	1, 551	315	489	3, 913	--------	28	7. 16	741
1961	1, 714	278	477	3, 816	--------	20	5. 24	215
1962	1, 605	297	477	3, 819	--------	22	5. 76	199
1963	1, 428	312	446	3, 633	1	27	7. 71	1, 888
1964 [p]	1, 500	312	465	3, 720	--------	20	5. 38	152
Total: [3]								
1955–59 (average)	39, 768	330	13, 120	104, 820	9	1, 497	14. 37	NA
1960	36, 160	317	11, 459	91, 572	7	994	10. 93	1, 000
1961	35, 547	323	11, 483	91, 862	6	1, 247	13. 64	1, 179
1962	34, 824	327	11, 378	90, 975	10	1, 010	11. 21	1, 147
1963	33, 072	340	11, 240	90, 019	7	927	10. 38	965
1964 [p]	34, 800	330	11, 472	92, 350	8	985	10. 75	1, 103

[p] Preliminary. NA Not available.

[1] Aluminum included with miscellaneous prior to 1960.

[2] Includes aluminum prior to 1960.

[3] Data may not add to total shown because of rounding.

NONMETAL (EXCEPT STONE) MINES AND MILLS

The overall injury experience at nonmetal mines in 1964 was improved, but at the mills the experience was less favorable than in 1963. At the mines both the injury frequency and severity rates were reduced, respectively, to 26.01 and 4,590 per million man-hours in 1964. However, at nonmetal mills the frequency rate increased to 20.47 and the severity rate to 1,362.

At clay and shale mines and mills both the frequency and severity rates of injuries increased markedly in 1964, owing principally to the increased numbers of fatal and nonfatal injuries. There was substantial improvement in the injury rate at gypsum mines, but this was offset by the less favorable frequency and severity rates at the mills in 1964. At phosphate rock operations the rates of occurrence of injuries were higher in both mining and milling activities. However, the severity rates were improved in 1964 for both activities. The safety record of potash mines was markedly better in 1964, and both the injury frequency and severity rates were well below the corresponding data for 1963. A major disaster (a single accident in which five men or more lose their lives) occurred in 1963 when 18 fatalities resulted from a gas explosion in a potash mine in Utah. At potash mills in 1964, both the frequency and severity rates of injuries were less favorable than in 1963.

At salt mines, the rate of occurrence of injuries was worse in 1964, but the severity rate was improved appreciably, compared with the 1963 figures. The safety record in salt mills was less favorable in 1964, and both the frequency and severity rates were higher than in 1963. Injury experience in the sulfur industry was better at both mines and mills in 1964. At operations working miscellaneous nonmetallic minerals, the injury-frequency rates were improved at both mines and mills in 1964. However, the severity rates at mines and mills were substantially worse owing to four fatalities at mines and one fatality at the mills.

The increased numbers of men working at clay-shale, potash, salt, and miscellaneous nonmetal mines in 1964 more than offset the relatively minor declines in employment at gypsum, phosphate rock, and sulfur mines. Employment increased slightly at mills of most of the nonmetallic mineral industries and decreased only at gypsum, potash, and sulfur mills.

TABLE 4.—Employment and injury experience at nonmetal (except stone) mines in the United States, by industry groups

Industry and year	Men working daily	Average active mine days	Man-days worked (thousands)	Man-hours worked (thousands)	Number of injuries		Injury rates per million man-hours	
					Fatal	Nonfatal	Frequency	Severity
Clay-shale:								
1960	6,209	192	1,193	9,638	5	272	28.74	4,897
1961	5,896	194	1,144	9,220	3	189	20.82	4,533
1962	5,383	185	995	8,031	1	230	28.76	2,464
1963	4,651	199	927	7,490	1	192	25.77	1,659
1964 [p]	5,400	206	1,106	8,970	7	245	28.09	6,547
Gypsum:								
1960	1,178	251	296	2,387	1	33	14.24	3,811
1961	1,100	249	274	2,215	1	27	12.64	3,431
1962	1,105	251	277	2,230	-------	19	8.52	2,376
1963	992	256	254	2,051	1	23	11.70	3,841
1964 [p]	950	252	239	1,930	-------	15	7.77	317
Phosphate rock:								
1960	2,352	289	679	5,419	-------	112	20.67	754
1961	2,373	271	644	5,253	2	73	14.28	3,070
1962	1,974	257	507	4,122	2	70	17.47	4,382
1963	2,012	279	561	4,536	3	72	16.53	5,088
1964 [p]	1,900	289	540	4,350	2	90	21.15	4,131
Potash:								
1960	1,603	315	506	4,046	1	176	43.75	2,360
1961	1,708	314	537	4,294	5	169	40.52	7,959
1962	1,602	306	491	3,925	5	181	47.38	8,846
1963	1,723	353	608	4,851	19	206	46.38	24,431
1964 [p]	2,000	335	670	5,350	4	165	31.59	6,161
Salt:								
1960	1,292	261	337	2,771	1	109	39.70	3,300
1961	1,444	255	368	3,067	2	101	33.57	6,666
1962	1,625	267	434	3,635	2	164	45.67	4,289
1963	1,532	270	414	3,443	3	113	33.69	6,214
1964 [p]	1,600	273	442	3,640	1	125	34.62	4,240
Sulfur:								
1960	1,878	346	650	5,558	5	167	30.95	6,817
1961	1,656	350	580	4,971	-------	93	18.71	612
1962	1,468	353	518	4,407	-------	72	16.34	748
1963	1,366	361	493	4,247	1	61	14.60	1,816
1964 [p]	1,300	362	476	4,110	-------	55	13.38	414
Miscellaneous:								
1960	4,141	206	853	6,985	6	187	27.63	NA
1961	4,104	195	800	6,496	2	209	32.48	3,222
1962	3,760	201	757	6,133	4	208	34.57	6,858
1963	3,294	223	733	5,921	3	190	32.60	4,117
1964 [p]	3,700	215	790	6,170	4	190	31.44	5,030
Total: [1]								
1960	18,653	242	4,515	36,805	19	1,056	29.21	4,478
1961	18,281	238	4,347	35,517	15	861	24.66	4,058
1962	16,917	235	3,979	32,484	14	944	29.49	4,275
1963	15,570	256	3,990	32,539	31	857	27.29	6,630
1964 [p]	16,800	254	4,264	34,520	18	880	26.01	4,590

[p] Preliminary. NA Not available.

[1] Data may not add to totals shown because of rounding.

TABLE 5.—Employment and injury experience at nonmetal (except stone) mills in the United States, by industry groups

Industry and year	Men working daily	Average active mill days	Man-days worked (thousands)	Man-hours worked (thousands)	Number of injuries		Injury rates per million man-hours	
					Fatal	Nonfatal	Frequency	Severity
Clay-shale:								
1960	20,222	247	4,991	40,784	6	1,121	27.63	2,070
1961	20,532	247	5,068	40,593	2	1,107	27.32	1,032
1962	17,142	233	3,987	32,756	3	796	24.39	1,539
1963	15,746	250	3,942	31,762	-------	881	27.74	836
1964 *p*	16,100	258	4,155	33,590	4	1,020	30.49	2,022
Gypsum:								
1960	2,464	261	642	5,146	2	18	3.89	2,674
1961	1,691	254	430	3,445	-------	19	5.52	1,998
1962	1,690	257	434	3,517	-------	21	5,97	289
1963	1,615	289	466	3,731	-------	14	3.75	294
1964 *p*	1,500	274	421	3,380	-------	20	5.92	2,173
Phosphate rock:								
1960	2,188	293	642	5,188	1	61	11.95	1,502
1961	2,523	279	705	5,644	1	50	9.04	2,078
1962	2,381	299	712	5,699	2	53	9.65	2,631
1963	2,297	310	712	5,714	1	29	5.25	1,260
1964 *p*	2,400	312	757	5,910	-------	35	5.92	970
Potash:								
1960	978	329	322	2,572	-------	118	45.88	900
1961	1,052	331	348	2,786	1	81	29.43	2,887
1962	712	305	217	1,737	-------	58	33.39	716
1963	1,020	330	337	2,695	1	25	9.65	2,612
1964 *p*	750	351	264	2,120	1	45	21.70	2,847
Salt:								
1960	5,000	282	1,410	11,304	1	159	14.15	1,066
1961	4,711	286	1,347	10.811	-------	174	16.09	453
1962	4,429	269	1,190	10,259	3	196	19.40	2,381
1963	4,539	301	1,368	10,999	-------	182	16.55	369
1964 *p*	4,600	291	1,332	10,250	-------	170	16.59	684
Sulfur:								
1960	51	216	11	92	-------	8	86.96	1,003
1961	33	182	6	49	-------	1	20.41	408
1962	34	265	9	69	-------	-------	-------	-------
1963	20	300	6	47	-------	1	21.28	553
1964 *p*	10	273	3	20	-------	-------	-------	-------
Miscellaneous:								
1960	8,665	307	2,661	21,300	3	309	14.65	NA
1961	8,489	303	2,568	20,597	2	248	12.14	1,317
1962	8,512	301	2,563	20,585	1	259	12.63	1,279
1963	8,495	309	2,621	20,996	-------	344	16.38	514
1964 *p*	8,600	309	2,659	21,300	1	270	12.72	898
Total: [1]								
1960	39,568	270	10,679	86,386	13	1,794	20.92	1,705
1961	39,031	268	10,471	83,925	6	1,680	20.09	1,199
1962	34,900	261	9,112	74,621	9	1,383	18.65	1,587
1963	33,732	280	9,452	75,944	2	1,476	19.45	589
1964 *p*	34,000	282	9,590	76,500	6	1,560	20.47	1,362

p Preliminary. NA Not available.

[1] Data may not add to totals shown because of rounding.

STONE QUARRIES AND MILLS

The overall safety record of all stone quarries and mills in 1964 showed only moderate changes from that of 1963. The rate of occurrence of injuries increased to 19.03 per million man-hours, from 18.22 in 1963. The severity rate was improved to 2,797 days lost per million man-hours, compared with 2,913 in 1963. There were 61 fatalities in 1964, the same as in the preceding year. However, the number of nonfatal injuries increased 312 to a total of 3,780 in 1964.

The injury-frequency rate was improved compared with 1963 data at limestone, slate, traprock, and miscellaneous stone operations but was less favorable at cement, granite, lime, marble, and sandstone quarries and mills. Cement operations attained the lowest rate of occurrence, 5.53 injuries per million man-hours, and the highest was recorded for granite quarries and mills with 33.07 per million man-hours.

The severity rate was improved in 1964 at cement, granite, marble, traprock, and miscellaneous stone operations. This measure of injury experience was less favorable at lime, limestone, sandstone, and slate quarries and mills.

Operating activity generally was higher in the stone industries during 1964. Man-hours worked increased slightly to moderately in each of the stone industries except cement operations for which a slight decrease was reported. Employment in 1964 exhibited similar trends, and the average number of men working was lower than in 1963 only at cement operations.

TABLE 6.—Employment and injury experience at stone quarries and mills in the United States, by industry groups

Industry and year	Men working daily	Average active plant days	Man-days worked (thousands)	Man-hours worked (thousands)	Number of injuries		Injury rates per million man-hours	
					Fatal	Nonfatal	Frequency	Severity
Cement:[1]								
1955–59 (average)	28,878	NA	NA	72,880	10	304	4.31	NA
1960	28,837	NA	NA	70,846	5	334	4.79	NA
1961	27,028	308	8,336	66,732	2	259	3.91	NA
1962	25,564	306	7,817	62,545	8	251	4.14	1,077
1963	24,956	309	7,715	61,727	7	306	5.07	950
1964 [p]	24,100	314	7,575	60,990	7	330	5.53	918
Granite:								
1955–59 (average)	7,065	NA	NA	14,092	5	598	42.79	NA
1960	8,532	NA	NA	16,563	2	551	33.39	NA
1961	8,329	234	1,949	16,192	4	547.	34.03	NA
1962	8,239	229	1,886	15,870	7	425	27.22	5,052
1963	8,131	234	1,900	15,797	13	423	27.60	7,393
1964 [p]	8,300	266	2,215	16,360	6	535	33.07	4,301
Lime:[1]								
1955–59 (average)	8,085	NA	NA	18,890	4	399	21.33	NA
1960	8,295	NA	NA	20,036	8	372	18.97	NA
1961	8,485	291	2,466	19,775	3	348	17.75	NA
1962	7,690	289	2,222	17,847	5	312	17.76	2,216
1963	7,439	300	2,230	17,890	3	237	13.42	1,716
1964 [p]	8,700	288	2,496	20,130	6	340	17.18	2,229
Limestone:								
1955–59 (average)	28,230	NA	NA	55,319	23	1,873	34.27	NA
1960	33,453	NA	NA	66,250	13	2,072	31.47	NA
1961	31,923	229	7,322	61,717	15	1,903	31.08	NA
1962	32,931	229	7,538	64,570	33	1,415	22.43	4,830
1963	33,093	230	7,603	64,500	29	1,499	23.69	3,958
1964 [p]	33,600	230	7,740	67,660	34	1,520	22.97	4,566
Marble:								
1955–59 (average)	2,820	NA	NA	5,864	1	215	36.83	NA
1960	3,093	NA	NA	6,457	2	308	48.01	NA
1961	3,119	245	765	6,257	2	289	46.51	NA
1962	2,919	247	721	5,938	3	260	44.29	4,419
1963	2,792	254	710	5,763	1	168	29.33	3,454
1964 [p]	2,900	256	733	5,940	--------	195	32.83	849
Sandstone:								
1955–59 (average)	3,441	NA	NA	6,234	1	304	48.93	NA
1960	4,701	NA	NA	7,770	3	374	48.52	NA
1961	4,370	206	900	7,404	2	327	44.44	NA
1962	5,867	219	1,282	10,802	3	267	25.00	3,444
1963	5,982	222	1,329	11,096	2	334	30.28	2,844
1964 [p]	6,500	224	1,467	12,310	4	395	32.41	3,243
Slate:								
1955–59 (average)	1,437	NA	NA	2,995	1	147	49.42	NA
1960	1,273	NA	NA	2,451	--------	117	47.74	NA
1961	1,160	251	292	2,359	--------	135	57.23	NA
1962	1,224	243	298	2,510	3	77	31.87	7,970
1963	1,270	264	335	2,719	--------	103	37.88	1,047
1964 [p]	1,400	263	374	3,030	1	90	30.03	3,122
Traprock:								
1955–59 (average)	3,564	NA	NA	6,632	4	300	45.84	NA
1960	5,207	NA	NA	8,835	4	411	46.97	NA
1961	4,979	220	1,097	9,079	4	407	45.27	NA
1962	5,734	215	1,235	10,197	4	224	22.36	4,284
1963	6,254	216	1,351	11,146	2	319	28.80	2,014
1964 [p]	6,600	213	1,410	11,740	2	285	24.45	1,949
Miscellaneous:[2]								
1957–61 (average)	1,744	209	364	3,082	1	127	41.53	NA
1962	2,071	190	393	3,173	1	68	21.75	3,865
1963	2,043	186	379	3,046	4	79	27.25	8,524
1964 [p]	2,400	192	453	3,640	1	85	23.63	1,897
Total:[3]								
1955–59 (average)	84,486	NA	NA	184,718	51	4,227	23.16	NA
1960	95,304	NA	NA	202,366	39	4,668	23.26	NA
1961	91,371	257	23,524	192,705	32	4,280	22.38	NA
1962	92,241	254	23,393	193,453	67	3,299	17.40	3,201
1963	91,960	256	23,553	193,685	61	3,468	18.22	2,913
1964 [p]	94,600	259	24,462	201,790	61	3,780	19.03	2,797

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[p] Preliminary. NA—Not available.

[1] Includes burning or calcining and other mill operations.

[2] Not compiled before 1957.

[3] Data may not add to total shown because of rounding.

SAND AND GRAVEL OPERATIONS

Injury experience at sand and gravel operations was improved in 1964 in the frequency rate which was lowered to 19.23 injuries per million man-hours, from 20.12 in 1963. However, the severity rate in 1964 advanced to 3,472 days lost per million man-hours, compared with 3,097 in the preceding year. A total of 33 fatalities was reported, the same as in 1963. The number of nonfatal injuries increased slightly to 1,905, 11 more than in 1963.

Sand and gravel operations were more active in 1964, and both employment and man-hours of worktime increased moderately over those of 1963.

TABLE 7.—Employment and injury experience at sand and gravel plants in the United States

Year	Men working daily	Average active plant days	Man-days worked (thousands)	Man-hours worked (thousands)	Number of injuries		Injury rates per million man-hours	
					Fatal	Nonfatal	Frequency	Severity
1960	52,352	NA	NA	95,749	25	1,919	20.30	2,434
1961	55,726	217	12,117	101,707	21	1,814	18.04	2,331
1962	53,599	218	11,690	97,589	51	2,093	21.97	4,232
1963	52,804	216	11,400	95,786	33	1,894	20.12	3,097
1964 p	55,400	216	11,951	100,760	33	1,905	19.23	3,472

p Preliminary. NA Not available.

SLAG (IRON-BLAST-FURNACE) OPERATIONS

The frequency rate of injuries increased sharply in 1964 owing to the larger number of injuries, 56 as compared with 37 in 1963. However, the severity rate was moderately improved principally because there was one fatality in 1964, compared with two (revised) in 1963. Operating activity was higher in 1964, and both employment and man-hours worked were slightly above the corresponding data for 1963.

TABLE 8.—Employment and injury experience at slag (iron-blast-furnace) plants in the United States

Year	Men working daily	Average active plant days	Man-days worked (thousands)	Man-hours worked (thousands)	Number of injuries		Injury rates per million man-hours	
					Fatal	Nonfatal	Frequency	Severity
1960	1,680	NA	NA	3,613	--------	34	9.41	1,050
1961	1,682	246	415	3,361	--------	30	8.93	248
1962	1,462	248	362	2,927	--------	29	9.91	417
1963	1,421	252	358	2,867	r 2	35	12.90	4,562
1964	1,440	265	380	3,040	1	55	18.42	3,981

Revised. NA Not available.

Abrasive Materials

By Paul M. Ambrose[1]

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THE ABRASIVES INDUSTRY throughout the world enjoyed a profitable year. With the exception of tripoli, the quantity of each kind of abrasive produced in the United States was greater than for any of the past 5 years and value of each was greater than for many years. Production of silicon carbide both in the United States and in Canada was the largest since 1960.

Abrasive machining, which offers great potential for the increased use of aluminum oxide, contributed to increased industrial productivity. Diamonds from the sea off the coast of South-West Africa attracted wide interest. Much of the production from this source has been gem diamond, and there is little likelihood of significant quantities of industrial diamond from that source. Manufactured diamond from all free-world sources was sold in the United States in 1964.

Foreign Trade.—An increase of $12 million in value of imports for consumption of abrasive materials was due largely to the $10-million increase in the value of diamond, exclusive of diamond dies. Import data for all individual classes in 1964 are not directly comparable with the 1963 data because of adoption of new import classifications September 1, 1963.

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[1] Commodity Specialist, Division of Minerals.

TABLE 1.—Salient abrasive statistics in the United States

Kind	1955-59 (average)	1960	1961	1962	1963	1964
Natural abrasives (domestic) sold or used by producers:						
Tripoli...short tons	49, 080	57, 713	54, 641	61, 732	66, 635	64, 613
Value...thousands	$203	$247	$225	$244	$266	$268
Special silica-stone products [1] short tons	5, 179	2, 539	2, 495	2, 653	2, 693	3, 186
Value...thousands	$370	$241	$238	$260	$255	$292
Garnet...short tons	11, 659	10, 522	12, 057	14, 166	14, 626	16, 123
Value...thousands	$1, 085	$986	$1, 036	$1, 172	$1, 412	$1, 622
Emery...short tons	10, 205	8, 169	6, 180	4, 316	6, 732	9, 214
Value...thousands	$157	$142	$106	$71	$119	$172
Artificial abrasives [2]...short tons	419, 291	441, 508	372, 192	423, 412	402, 823	459, 169
Value...thousands	$56, 828	$64, 594	$54, 937	$59, 854	$56, 523	$63, 370
Foreign trade (natural and artificial abrasives):						
Imports for consumption (value) thousands	$85, 431	$84, 488	$96, 219	$79, 473	r $77, 500	$89, 495
Exports (value)...do	$24, 976	$26, 550	$29, 209	$32, 757	$35, 774	$44, 102
Reexports (value)...do	$9, 913	$10, 409	$17, 814	$11, 454	$12, 918	$17, 142

r Revised.

[1] See table 6 for kind of products.

[2] Production of silicon carbide and aluminum oxide (United States and Canada); shipments of metallic abrasives (United States).

TABLE 2.—U.S. imports for consumption of abrasive materials (natural and artificial), by kinds

Kind	1963		1964	
	Quantity	Value	Quantity	Value
Burrstones in block, rough...short tons	r 22	r $930	-----------	-----------
Corundum, crude or crushed...do	2, 035	51, 334	1, 969	$53, 130
Emery, flint, rottenstone, and tripoli, crude or crushed short tons	r 15, 749	r 398, 887	18, 519	517, 632
Silicon carbide, crude...do	68, 214	r 8, 434, 401	79, 557	9, 659, 262
Aluminum oxide, crude...do	134, 875	13, 473, 368	136, 391	14, 099, 179
Other crude artificial abrasives...do	1, 148	165, 255	2, 764	270, 402
Abrasives, ground, grains, pulverized or refined:				
Rottenstone and tripoli...short tons	-----------	-----------	(1)	1, 080
Silicon carbide...do	150	52, 358	603	205, 636
Aluminum oxide...do	1, 189	250, 185	253	772, 450
Emery, corundum, flint, garnet, and other, including artificial abrasives...short tons	8, 205	1, 803, 302	99	26, 341
Papers, cloths, and other materials wholly or partly coated with natural or artificial abrasives	(2)	1, 526, 201	(2)	1, 788, 809
Hones, whetstones, oilstones, and polishing stones number	r 251, 684	r 62, 093	234, 526	52, 322
Burrstones, manufactured or bound up into millstones short tons	17	2, 795	-----------	-----------
Abrasive wheels:				
Solid natural stone wheels...number	100	222	4, 878	6, 845
Diamond...do	7, 163	28, 616	12, 483	108, 757
Other	(2)	r 434, 583	(2)	553, 261
Articles n.s.p.f.:				
Emery or garnet	(2)	5, 986	(2)	9, 406
Natural corundum or of artificial abrasive materials	(2)	24, 586	(2)	37, 878
Other	(2)	63, 723	(2)	66, 053
Grit, shot, sand, or iron and steel...short tons	r 1, 613	r 667, 633	4, 346	1, 052, 296
Diamonds:				
Diamond dies...number	9, 305	169, 415	8, 022	163, 711
Crushing bort...carats	r 4, 211, 417	r 10, 874, 529	3, 901, 982	9, 779, 551
Other industrial diamonds...do	r 5, 180, 695	32, 168, 418	6, 937, 526	39, 556, 615
Miner's diamonds...do	r 158, 555	r 778, 908	782, 391	4, 074, 312
Dust and powder...do	2, 295, 486	6, 061, 975	2, 752, 382	6, 640, 430
Total	-----------	r 77, 499, 703	-----------	89, 495, 358

r Revised.

[1] Less than ½ unit.

[2] Quantity not recorded.

Source: Bureau of the Census.

TABLE 3.—U.S. exports of abrasive materials, by kinds

Kind	1963		1964	
	Quantity	Value	Quantity	Value
Natural abrasives:				
Diamond-grinding wheels, sticks, hones, and laps ---carats--	373,053	$2,353,883	405,328	$2,708,712
Diamond dust and powder ---do----	r 1,110,237	r 3,019,865	1,892,097	4,097,482
Diamond suitable only for industrial use---do----	r 1,054,239	r 3,265,416	1,324,195	4,710,488
Grindstones and pulpstones---short tons--	41	34,210	179	48,460
Emery powder, grains, and grit (natural)-pounds--	1,251,128	250,812	1,360,129	199,025
Corundum grains and grits (natural)---do----	150,622	47,930	308,386	73,666
Whetstones, sticks, etc. (natural)---do----	138,475	162,257	271,942	162,950
Natural abrasives not elsewhere classified---do----	25,450,422	1,397,988	27,981,930	1,831,076
Manufactured abrasives:				
Aluminum oxide, fused, crude, and grains---do----	26,273,280	4,075,951	37,421,869	5,611,540
Silicon carbide, fused, crude, and grains---do----	19,625,889	3,309,004	22,430,140	3,863,948
Alumina, unfused---do----	375,481	100,486	902,253	143,651
Manufactured abrasives, not elsewhere classified pounds--	207,393	109,847	346,905	113,907
Abrasive pastes, compounds, and cake (except chemical)---pounds--	830,749	254,710	883,682	294,016
Grinding wheels except diamond wheels---do----	3,050,860	4,342,904	3,340,038	4,485,107
Pulpstones of manufactured abrasives---do----	2,842,296	777,755	3,278,133	871,112
Whetstones, etc., of manufactured abrasives--do----	306,112	1,046,569	472,847	1,261,764
Abrasive paper and cloth (natural abrasives) reams--	30,769	608,495	31,729	645,282
Abrasive paper and cloth (artificial abrasives)-do----	272,690	9,453,860	509,987	11,575,157
Metallic abrasives (except steel wool)---pounds--	14,537,303	1,161,807	17,290,096	1,404,483
Total---	---	35,773,749	---	44,101,826

r Revised.

Source: Bureau of the Census.

TABLE 4.—U.S. reexports of abrasive materials, by kinds

Kind	1963		1964	
	Quantity	Value	Quantity	Value
Natural abrasives:				
Diamond-grinding wheels, sticks, hones, and laps carats--	303	$4,814	950	$5,522
Diamond dust and powder---do----	153,853	350,350	185,037	373,269
Diamond suitable only for industrial use---do----	2,236,222	12,526,158	2,947,487	16,750,524
Emery powder, grains, and grits (natural) pounds--	14,560	1,593	10,500	1,155
Natural abrasives not elsewhere classified---do----	145,650	7,371	86,970	3,792
Manufactured abrasives:				
Alumina, unfused---do----	129,800	9,305	---	---
Aluminum oxide, fused, crude, and grains pounds--	6,073	1,883	600	286
Grinding wheels, except diamond wheels---do----	7,766	13,223	5,436	5,175
Whetstones, etc., of manufactured abrasives--do----	200	3,030	204	1,991
Total---	---	12,917,727	---	17,141,714

Source: Bureau of the Census.

TRIPOLI[2]

Output was by five companies: Ozark Minerals Co., Elco, Ill. (amorphous silica); Tamms Industries Co., Tamms, Ill. (amorphous silica); American Tripoli Division, The Carborundum Co., Seneca,

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[2] Tripoli includes tripoli from the Missouri-Oklahoma field, amorphous or soft silica from southern Illinois, and rottenstone from Pennsylvania. Although they differ in some respects, all are fine-grained, porous silica materials with many similar properties and end uses.

Mo., and Ottawa County, Okla. (Mo.-Okla.-tripoli); Penn Paint & Filler Co., Antes Fort, Pa. (rottenstone); and Keystone Filler & Manufacturing Co., Muncy, Pa. (rottenstone).

Processed tripoli prices remained virtually unchanged from 1963 according to quotations in E&MJ Metal and Mineral Markets. They were as follows (per pound, paper bags, minimum carlot 30 tons, f.o.b. Missouri): Once ground through 40 mesh, rose and cream colored, 2.75 cents; double ground through 110 mesh, rose and cream colored, 2.75 cents; and air floated through 200 mesh, 3 cents.

TABLE 5.—Processed tripoli[1] sold or used by producers in the United States, by uses[2]

Year	Abrasives		Filler		Other, including foundry facings		Total	
	Short tons	Value (thousands)	Short tons	Value (thousands)	Short tons	Value (thousands)	Short tons	Value (thousands)
1955–59 (average)	32,154	$1,358	7,695	$181	[3] 5,031	[3] $174	44,880	$1,713
1960	37,050	1,589	9,590	206	5,258	167	51,898	1,962
1961	34,581	1,472	9,409	231	4,605	149	48,595	1,852
1962	38,241	1,641	9,578	252	4,863	152	52,682	2,045
1963	38,979	1,645	10,145	276	5,619	197	54,743	2,118
1964	42,371	1,831	10,865	295	5,253	169	58,489	2,295

[1] Includes amorphous silica and Pennsylvania rottenstone.
[2] Partly estimated.
[3] Includes some tripoli for filter block in 1955.

SPECIAL SILICA-STONE PRODUCTS

Grindstone sales were reported from Ohio; grinding pebbles, from Minnesota and Wisconsin; tube-mill liners, from Minnesota and Wisconsin; and natural silica abrasive material for oilstones and other sharpening stones, from Arkansas and Indiana. There was no reported production of millstones in 1964.

TABLE 6.—Special silica-stone products sold or used by producers in the United States[1]

Year	Short tons	Value (thousands)	Year	Short tons	Value (thousands)
1955–59 (average)	5,179	$370	1962	2,653	$260
1960	2,539	241	1963	2,693	255
1961	2,495	238	1964	3,186	292

[1] Includes grinding pebbles, oilstones and other sharpening stones, tube-mill liners, grindstones, and value of millstones (1955–63).

NATURAL SILICATE ABRASIVES

Sales of domestic garnet abrasive grain which has no sales value until crushed, concentrated, and ground to definite particle size specifications by the producer, increased sharply for the second consecutive year, due largely to increased production in New York. Material from New York was used principally in glass grinding, metal lapping, and wood, leather, and plastic sanding. Idaho garnet was used in sandblasting. Producers in 1964 were Idaho Garnet Abrasive Co. and Emerald Creek Garnet Milling Co., Fernwood, Idaho; Porter Brothers Corp., Valley County, Idaho; Barton Mines Corp., North Creek, N.Y.; and Cabot Corp., Willsboro, N.Y.

The Idaho Garnet Abrasive Co., the world's second largest producer of garnet, at Fernwood, Benewah County, Idaho, was purchased by Sunshine Mining Co. Reserves were estimated to be sufficient to last 100 years at the present rate of mining. Garnet was mined by stripping up to 6 feet of overburden and then using a dragline to mine material for a portable washing and jigging plant.[3] The reported price was $700,000 for the plant and holdings of 965 acres of fee land in Benewah, Shoshone, and Latah Counties, Idaho.

TABLE 7.—Abrasive garnet sold or used by producers in the United States

Year	Short tons	Value (thousands)	Year	Short tons	Value (thousands)
1955-59 (average)	11,659	$1,085	1962	14,166	$1,172
1960	10,522	986	1963	14,626	1,412
1961	12,057	1,036	1964	16,123	1,622

NATURAL ALUMINA ABRASIVES

Corundum.—The American Abrasive Co., Westfield, Mass., was the sole domestic importer and processor of corundum, most of which was from Southern Rhodesia. According to data of the Bureau of the Census, imports in 1964 decreased 3 percent in quantity and increased 3 percent in value compared with those of 1963.

TABLE 8.—World production of corundum by countries [1] [2]

(Short tons)

Country [1]	1955-59 (average)	1960	1961	1962	1963	[p] 1964
Australia	2					
India	370	276	363	332	[r] 725	[3] 725
Malaysia	[4] 21					
Mozambique	2					
South Africa, Republic of	1,441	123	159	349	[r] 79	60
Southern Rhodesia	3,508	3,843	2,792	3,348	5,941	2,872
World total (estimate) [1] [2]	10,000	9,000	8,000	9,000	11,000	9,000

[p] Preliminary. [r] Revised.

[1] Corundum is produced in the U.S.S.R.; data on production are not available, and estimate is included in the total.

[2] Data do not add exactly to totals shown because of rounding where estimated figures are included in the detail.

[3] 1963 data.

[4] Exports.

Emery.—Sales of emery mined in the United States reached the highest level since 1957. Domestic producers were De Luca Emery Mine at De Luca No. 1 and De Luca No. 2, Peekskill, N.Y.; Di Rubbo American Emery Ore, Kingston Emery Mine, Croton-on-Hudson,

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[3] Metal Mining and Processing. V. 1, No. 3, March 1964, p. 23.

N.Y.; and Peekskill Emery Co., Peekskill, N.Y. As in recent years, the principal uses were in coated abrasives, grinding wheels, and in nonskid surfaces for floors, stairs, and pavements.

TABLE 9.—Emery sold or used by producers in the United States

Year	Short tons	Value (thousands)	Year	Short tons	Value (thousands)
1955-59 (average)	10,205	$157	1962	4,316	$71
1960	8,169	142	1963	6,732	119
1961	6,180	106	1964	9,214	172

INDUSTRIAL DIAMOND

Foreign and Industry Review.—Imports of bort in 1964 were less than the estimated capacity for producing manufactured diamond in the United States, and imports of crushing bort plus dust and powder were not as great as domestic capacity for manufacturing and reclaiming diamond. Only half as much bort was received from Congo (Léopoldville) in 1964 as in the previous year. The increase in imports of stones from Ghana was pronounced.

United States production of manufactured diamond suitable for use in grinding wheels and saws was probably about 5 million carats, and free-world production may have been twice that quantity. Little information is available on the manufacture of diamond in the U.S.S.R., but it is believed that production is increasing. In the free world diamond was manufactured in the United States, Ireland, Sweden, Japan, and the Republic of South Africa.

TABLE 10.—U.S. imports for consumption of industrial diamond (excluding diamond dies)

(Thousand carats and thousand dollars)

Year	Quantity	Value	Year	Quantity	Value
1955-59 (average)	13,456	$58,617	1962	12,281	$51,040
1960	13,146	51,836	1963	r 11,846	r 49,884
1961	14,210	68,545	1964	14,374	60,051

r Revised.

Source: Bureau of the Census.

Africa.—A concession to prospect for diamonds and other precious stones was granted to Angola Exploration Co. (Pty.). Formerly the only company exploiting diamond in Angola was Companhia de Diamantes de Angola which had an exclusive license to prospect for and mine diamonds in Angola.[4]

A committee was established in Basutoland by the Government to study and make recommendations on diamond marketing and police control. One of the reasons for needing the report was loss of revenue to the State from the smuggling of diamond.[5]

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[4] Mining Journal (London). Angola Diamond Concessions. V. 262, No. 6707, Mar. 6, 1964, p. 177.

———. Diamond Prospecting in Angola. V. 263, No. 6739, Oct. 16, 1964, p. 284.

[5] World Mining. V. 17, No. 1, January 1964, p. 63.

TABLE 11.—U.S. imports for consumption of industrial diamond (including diamond dust), by countries

Year and country	Crushing bort (including all types of bort suitable for crushing)		Other industrial diamond (including glazers' and engravers' diamond, unset)		Miners' diamond		Dust and powder	
	Carat	Value	Carat	Value	Carat	Value	Carat	Value
1963:								
North America:								
Canada	38,633	$99,658	121,790	$704,678			35,647	$105,001
Mexico	[r] 17,601	[r] 33,202			[r] 11,164	[r] $581		
Total	[r] 56,234	[r] 132,860	121,790	704,678	[r] 11,164	[r] 581	35,647	105,001
South America:								
Brazil	6	219	8,249	116,591	787	12,435		
British Guiana			382	7,570				
Venezuela	1,261	4,522	16,471	290,261				
Total	1,267	4,741	25,102	414,422	787	12,435		
Europe:								
Azores	8,636	21,881						
Belgium-Luxembourg	432,780	1,024,919	400,836	2,465,139			58,452	164,708
France			17,874	264,589	676	3,380	100	295
Germany, West			16,561	349,798				
Ireland			558,681	2,672,882	80,219	417,513	91,216	291,407
Malta, Gozo			65	982				
Netherlands	7,853	17,782	112,318	1,378,250	846	5,938	37,794	104,325
Spain					64	1,277		
Sweden			980	4,303				
Switzerland	407	988	71,352	843,513			23,803	42,226
United Kingdom	641,770	1,755,256	643,333	6,271,933	669	4,684	741,649	1,914,277
Total	1,091,446	2,820,826	1,822,000	14,251,389	82,474	432,792	953,014	2,517,238
Asia:								
Israel	544	1,632	31,294	304,355	6,406	32,057		
Japan			[r] 32,049	514,533			2,550	7,400
Total	544	1,632	[r] 63,343	818,888	6,406	32,057	2,550	7,400

TABLE 11.—U.S. imports for consumption of industrial diamond (including diamond dust), by countries—Continued

Year and country	Crushing bort (including all types of bort suitable for crushing)		Other industrial diamond (including glazers' and engravers' diamond, unset)		Miners' diamond		Dust and powder	
	Carat	Value	Carat	Value	Carat	Value	Carat	Value
1963—Continued								
Africa:								
British West Africa and Sierra Leone	66, 979	$176, 386	44, 524	$250, 359				
Congo (Léopoldville)	1, 687, 452	4, 283, 988	390, 916	1, 367, 723	1, 280	$8, 260	132, 300	$330, 972
Ghana	1, 397	2, 096	775, 493	3, 941, 928	28	956	2, 500	6, 000
Liberia			39, 074	276, 824				
Rhodesia and Malawi			1, 802	10, 223				
South Africa, Republic of	1, 216, 124	3, 217, 146	1, 428, 771	7, 530, 472	26, 816	139, 505	1, 150, 880	3, 059, 116
Western Africa, n.e.c.	84, 573	220, 753	400, 196	2, 004, 475	911	5, 963	3, 770	11, 660
Western Equatorial Africa, n.e.c.	5, 401	14, 101	67, 611	596, 673	28, 689	146, 359	4, 625	13, 307
Total	3, 061, 926	7, 914, 470	3, 148, 387	15, 978, 677	57, 724	301, 043	1, 294, 075	3, 421, 055
Oceania: Australia			73	364			10, 200	11, 281
Grand total	r 4, 211, 417	r 10, 874, 529	r 5, 180, 695	32, 168, 418	r 158, 555	r 778, 908	2, 295, 486	6, 061, 975
1964:								
North America:								
Canada	19, 672	110, 478	203, 234	1, 151, 217	15, 622	66, 855	9, 322	15, 162
Mexico	60, 330	120, 084			930	1, 860		
Total	80, 002	230, 562	203, 234	1, 151, 217	16, 552	68, 715	9, 322	15, 162
South America:								
Brazil			13, 943	169, 699	400	3, 382		
British Guiana			1, 630	32, 429				
Chile			372	198				
Colombia			131	1, 767				
Venezuela	76	114	12, 273	131, 737				
Total	76	114	28, 349	335, 830	400	3, 382		
Europe:								
Belgium-Luxembourg	415, 161	985, 707	606, 433	3, 281, 663	4, 557	44, 899	140, 402	340, 215
France	34, 850	54, 958	6, 431	62, 589	1, 362	6, 958		
Germany, West	6, 000	9, 300	33, 315	375, 245			3, 809	9, 136
Ireland	427, 000	1, 101, 946	393, 308	1, 020, 536	680, 797	3, 560, 484	743, 882	1, 954, 081
Italy							634	1, 584
Malta, Gozo			422	3, 150				

Netherlands	350, 876	836, 655	128, 651	929, 467	5, 905	47, 497	52, 460	130, 945
Sweden	------	------	1, 939	15, 460	------	------	------	------
Switzerland	5, 472	13, 133	18, 332	159, 882	151	814	25, 722	31, 542
United Kingdom	521, 545	1, 374, 229	893, 181	7, 580, 115	34, 256	171, 332	1, 084, 334	2, 376, 732
Total	1, 760, 904	4, 375, 928	2, 082, 012	13, 428, 107	727, 028	3, 831, 984	2, 051, 243	4, 844, 235
Asia:								
Hong Kong	------	------	47	579	------	------	------	------
Israel	92, 262	214, 822	17, 277	181, 500	5, 038	12, 635	------	------
Japan	------	------	35, 886	525, 772	1, 500	1, 485	7, 494	21, 534
Korea, South	------	------	2, 904	8, 350	------	------	------	------
Total	92, 262	214, 822	56, 114	716, 201	6, 538	14, 120	7, 494	21, 534
Africa:								
British West Africa and Sierra Leone	4, 748	11, 483	222, 271	4, 723, 771	------	------	6, 818	13, 358
Central African Republic	8, 362	21, 396	61, 960	895, 680	25, 617	120, 897	------	------
Congo (Léopoldville)	867, 694	2, 060, 894	283, 312	1, 002, 994	1, 000	5, 692	443, 914	1, 125, 209
Ghana	2, 500	9, 625	1, 206, 996	5, 859, 198	------	------	2, 176	6, 528
Guinea	------	------	313	2, 359	------	------	------	------
Ivory Coast	------	------	1, 869	19, 529	------	------	------	------
Liberia	7, 260	17, 884	3, 227	31, 554	200	1, 115	------	------
Maderia Islands	------	------	1, 514	7, 870	------	------	------	------
Portuguese Western Africa, n.e.c	------	------	3, 113	8, 404	------	------	------	------
South Africa, Republic of	1, 029, 307	2, 724, 698	2, 560, 014	10, 101, 336	1, 545	10, 852	210, 863	572, 197
Western Africa, n.e.c	48, 867	112, 145	223, 228	1, 272, 565	3, 511	17, 555	4, 552	13, 957
Total	1, 968, 738	4, 958, 125	4, 567, 817	23, 925, 260	31, 873	156, 111	668, 323	1, 731, 249
Oceania: Australia	------	------	------	------	------	------	16, 000	28, 250
Grand total	3, 901, 982	9, 779, 551	6, 937, 526	39, 556, 615	782, 391	4, 074, 312	2, 752, 382	6, 640, 430

r Revised.

Source: Bureau of the Census.

TABLE 12.—World production of natural industrial diamond, by countries

(Thousand carats)

Country	1963	1964
Africa:		
Angola	325	345
Central African Republic	282	221
Republic of Congo (Brazzaville) [1]	[2] 5,343	[e] 4,950
Republic of the Congo (Léopoldville)	14,468	14,457
Ghana	2,142	2,402
Guinea [2] [e]	32	32
Ivory Coast	117	80
Liberia [2]	508	272
Sierra Leone	833	774
South Africa, Republic of:		
"Pipe" mines:		
Premier	1,565	1,668
De Beers Group [3]	[r] 753	759
Others	[r] 36	41
"Alluvial" mines	[r] 225	192
South-West Africa	119	154
Tanzania	313	326
Total Africa	[r] 27,061	26,673
Other areas:		
Brazil [e]	175	175
British Guiana	40	49
Venezuela	31	58
U.S.S.R. [e]	2,760	2,760
World total [4]	[r] 30,067	29,715

[e] Estimated. [r] Revised.
[1] Probable origin, Republic of the Congo (Léopoldville).
[2] Exports.
[3] Includes some alluvial from De Beers properties.
[4] Does not include minor world production.

An eight-man partnership obtained a prospecting grant for diamond from the Bechuanaland Government. Prospecting was to be on a 13,000-square-mile area of the Kalahari Crown lands and restricted to an initial period of 1 year, renewable for additional 1-year periods.[6]

The Cameroon Ministry of Transportation, Mines, and Post and Telecommunications awarded diamond prospecting authority in Cameroon to Ivory Coast Diamond Corp.[7]

The Société Nationale de Recherches et d'Exploitations Minieres (SINAREX), a State-owned diamond mining firm, was established by the Central African Republic to increase diamond production and to curb the large number of nongovernment diamond buyers who acted as middlemen in the trade. SINAREX was to establish five or six diamond mining centers in the southwestern part of the country. It was hoped that most of the 15,000 individual diggers would be attracted to the centers and would use the facilities and sell their diamond to licensed buying offices. The operations or privately owned diamond companies would not be affected.[8]

New installations by Consolidated African Selection Trust, Ltd., at the Akwatia deposits in Ghana were to be completed by January 1965. Use of these facilities was expected to increase output by 400,000 carats per year.[9]

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[6] Mining Journal (London). Bechuanaland Diamond Prospecting Grant. V. 263, No. 6746, Dec. 4, 1964, p. 429.
[7] Bureau of Mines. Mineral Trade Notes. V. 59, No. 4, October 1964, p. 17.
[8] Bureau of Mines. Mineral Trade Notes. V. 58, No. 5, May 1964, pp. 17–18.
[9] Bureau of Mines. Mineral Trade Notes. V. 59, No. 3, Sept. 1964, pp. 14–20.

Because of prohibition by the Government of Ivory Coast of clandestine operations, production by native prospectors has virtually ceased. Production in 1963 was by three companies, but two others were continuing prospecting.[10]

In Mozambique a concession was granted for the exploration and mining of diamond on land and lake, river, and stream beds within the following boundaries: Eastern, 33° E Greenwich; southern, 24th parallel south; northern, 22d parallel south; western, South African and Southern Rhodesian borders. The company would have headquarters in Mozambique, with the president and half of its directors of Portugese nationality. The company would be exempt from customs duties, and after deducting 5 percent from net profits for its reserve, 50 percent of the remainder would be retained within Mozambique.[11]

Price increases by the Government Diamond Office of Sierra Leone resulted in a decreased ratio of industrial diamond to gem diamond produced.[12] The Government of Sierra Leone was planning to establish a diamond cutting industry in order to increase the foreign exchange value of exports. The arrangement whereby the Diamond Corp. buys the production of Sierra Leone Selection Trust was to continue for 2 years after current agreements expire.[13]

Litigation between the Transvaal and Orange Free State Chamber of Mines and General Electric Co., concerning a method for manufacturing diamond, was decided in favor of General Electric Co. in a court in South Africa. Four applications for manufacturing diamond were involved. Expenses of expert witnesses were also allowed. Notice of appeal was given by the Chamber of Mines.[14]

Treasure Trove Diamonds Ltd., a small-scale diamond producer, reopened its West End mine in Northern Cape Province. Seven hundred loads, yielding 15.6 carats per 100 loads, were being mined daily from a 12-foot-diameter shaft sunk to 480 feet. Original plans provided for sinking the shaft to 1,000 feet.[15] The South African Government issued a diamond mining license to Coronation Freehold's Blaauwbosch property. Options were taken on adjacent farms. Improvements at the washing plant were being made so that a minimum of 1,000 loads a day could be processed.[16] The Finsch mine, South Africa's first new diamond mine in 50 years, started production in mid-December 1964. Open-cast mining methods were to be used to a depth of 300 feet. Open-cast methods may be used to 600 feet, or a shaft may be sunk and underground methods used. Overburden of ironstone rubble and yellow ground, each containing some diamond, was being removed at the rate of 12,000 loads per day. Overburden was being screened, and ½-inch material was saved for further treatment. Stripping was to take a year, and 400 loads of yellow ground per day were to be concentrated in a pilot plant that was being used to determine final details of the main treatment plant. In full operation the mine would require 1.5 million gallons of water a day; 100 houses were being erected and dormitory housing for 300 workers was being provided.[17]

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[10] Bureau of Mines. Mineral Trade Notes. V. 59, No. 1, July 1964, p. 13.

[11] Bureau of Mines. Mineral Trade Notes. V. 59, No. 5, Nov. 1964, p. 21.

[12] Bureau of Mines. Mineral Trade Notes. V. 59, No. 4, Oct. 1964, p. 17.

[13] Mining Journal (London). Sierra Leone Diamonds. V. 262, No. 6713, Apr. 17, 1964, p. 303.

[14] Electronic News. South Africa Awards GE Patents for Diamond Process. V. 9, No. 468, Dec. 28, 1964, p. 24.

[15] World Mining. V. 17, No. 10, Sept. 1964, p. 82.

[16] Mining Journal (London). Diamond Mining Prospects Granted. V. 263, No. 6730, Aug. 14, 1964, p. 116.

An increase in diamond production by Consolidated Diamonds in South-West Africa, requiring the erection of two new field screening plants and additional equipment, was expected. The ore reserve was estimated at 72.5 million cubic meters containing 25.5 million carats.[18]

Production of diamond from the ocean off the coast of South-West Africa for the first 11 months of 1964 was 265,567 carats, well below the goal of 2,500 carats per day. Three vessels, Diamantkus, Barge III, and Colpontoon, were used, and it was planned to have a fourth vessel, Barge 177, begin work.[19]

Another program of prospecting for diamond, in the Atlantic off the coast of South-West Africa, was started in March. The sampling ship, the M.V. *Rockeater*, length—180 feet, beam—32 feet, draft—9 feet, displacement—800 tons, was fitted with a 500-kw powerplant, circulating pumps, air compressors, and hydraulic plant. The heavy media and processing equipment had a capacity of 20 tons per hour of gravel samples.[20]

It was reported that the Government of Tanganyika was considering severing business relations with the De Beers group. A severance of relations would require purchase of the De Beers interest in the Williamson mine, and benefits of marketing through the Central Selling Organization would be lost. There would also be a problem in finding a trained staff to operate the Williamson mine.[21]

Diamond exploration rights to almost all of Upper Volta were awarded to West African Selection Trust, Ltd., a British firm, for 1 year beginning January 1, 1964. The Trust had agreed to spend $62,000 a year for exploration through its subsidiary Selection Trust Explorations, Ltd. Some traces of diamond have been found near the Ghanaian border.[22]

Brazil.—The Tejucana group, including Pacific Tin Co., has been prospecting on the Jequitinhonha River northeast of Diamantina, Minas Gerais. As a result of 3 years of prospecting 1 lot of uncut stones was sold. Of the 2,245 carats, 1,000 was classified as industrial stones. It was hoped to develop the diamondiferous gravels with bucketline dredges if suitable financing could be arranged.[23]

Canada.—Rock blasted on Ile Ronde, Montreal, while preparing the World's Fair site, was said to be distantly related to kimberlite, the diamond-bearing rock of South Africa. Diamonds may be embedded in the rock at great depths.[24] Diamond interests were actively prospecting in Canada.

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[17] South African Mining and Engineering Journal (Johannesburg). Mining Starts at Finsch Diamond Mine. V. 75, pt. 2, No. 3739, Oct. 2, 1964, pp. 960–961.

[18] South African Mining and Engineering Journal (Johannesburg). Mining Activities in S.W.A. V. 75, pt. 2, No. 3725, June 26, 1964, pp. 187–188, 191.

[19] Mining Journal (London). Higher Production This Month? V. 263, No. 6748, Dec. 18, 1964, pp. 477–478.

[20] Industrial Diamond Review. Prospecting Ship Searches South-West African Sea Bed. V. 24, No. 282, May 1964, pp. 120–121.

[21] Mining Journal (London). Tanganyika and De Beers. V. 263, No. 6731, Aug. 21, 1964, p. 127.

[22] Bureau of Mines. Mineral Trade Notes. V. 58, No. 5, May 1964, p. 23.

[23] Mining Journal (London). Diamonds Exported From Brazil. V. 263, No. 6744, Nov. 20, 1964, p. 378.

[24] Engineering and Mining Journal. Canadian Quarry Yields Diamond-Bearing Rock. V. 165, No. 4, April 1964, p. 142.

India.—Two new diamond mines were being developed at Majgawar and Ramkhiria at an estimated cost of $2.1 million. When completed, the mining operations were estimated to be capable of producing 42,500 carats annually with a possible net return of $8.4 million.[25]

U.S.S.R.—A special geomorphological map of the Yakutian placers was compiled, with special attention being given to gold, diamond, and platinum placers in the Urals. Diamond production was likely to increase because of the newly discovered Prilensk field and the reported find of high-quality diamonds on the slopes of the Anabar shield in north central Siberia, the Urals, and occasional crystals found near the middle Dnieper.[26] Much geologic information on Siberian diamond deposits was made available.[27] A new mill for year-round concentration of Siberian diamond was recently completed at Mirny. Special foundations in the permafrost support the steel framework, and the outside is covered with insulated aluminum panels. After the discovery of Mir, geologists found additional pipes named Aikhal and Udachnaya. Other pipes with a higher diamond content might exist north of Mir.[28] Because of Soviet support of a trade boycott of South Africa, De Beers Consolidated Mines, Ltd., announced that it would renew its contract to sell Soviet diamond in the West.

Technology.—Diamond machining was used on relatively soft materials to give a highly finished edge and to maintain the planned shape and finish of glassfibre and of resin rubber shoe soles. Diamond tools were used for sawing, routing, trimming, drilling, surface planing, and thicknessing all forms of fibreglass reinforced plastics. Finishes produced with diamond were superior to those produced using steel or even carbide-tipped tools.[29] Abrasive stones were used to finish the edges of resin rubber shoe soles. Up to 7,000 pairs of men's soles or 9,000 pairs of women's soles could be finished, but on long runs the profile deteriorated and the pattern lost its original sharpness. Substituting specially designed diamond surface trimming wheels for other abrasives resulted in as many as 50,000 pairs of soles with a consistently good finish.[30]

Glass sheets of up to 7 by 4 meters, mainly for mirrors and doors, were being cut by using a single point diamond cutter. The edges of glass shapes up to 2.134 meters wide and 12 mm thick were being smoothed at 300 to 600 meters per hour depending on the thickness. Eight metal bonded diamond wheels in pairs could grind two sides of the glass panel at the same time. Thin walled, water-cooled core drills turning at 3,000 rpm could complete two holes in a door in 1 minute. Slots for hinge assemblies were cut with a metal bonded diamond saw.[31]

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[25] Mining Journal (London). Diamond Mining at Panna. V. 262, No. 6709, Mar. 20, 1964, p. 216.

[26] Mining Journal (London). Soviet Placers. V. 263, No. 6727, July 24, 1964, p. 58.

[27] Economic Geology. The Geology of Diamond Deposits. V. 59, No. 6, Sept.–Oct. 1964, p. 1188.

———. Kimberlitic Rocks and Picritic Porphyries of the Northeast Part of the Siberian Platform. V. 59, No. 6, Sept.–Oct. 1964, p. 1188.

[28] World Mining. How Russia Mines More Diamonds. V. 17, No. 13, Dec. 1964, p. 35.

[29] Saville, P. A. Machining of Glassfibre Reinforced Plastics. Industrial Diamond Review, v. 24, No. 279, Feb. 1964, pp. 26–29.

[30] Industrial Diamond Review. Keeping in Step With Diamonds. V. 24, No. 279, Feb. 1964, p. 43.

[31] Finnigan, G. French Glass Company Overcomes Production Problems. Industrial Diamond Review, v. 24, No. 280, Mar. 1964, pp. 69–71.

An X-ray camera with diamond anvils mounted on steel seats was being used at Standard Telecommunications Laboratories at Harlow, Essex, England, to study systems at high pressures. A strip of film was exposed for 6 hours to X-rays passed through the diamonds. Pressures used thus far have been restricted to 60,000 atmospheres, although it was thought to be capable of being used at 100,000 atmospheres. One new material, stishovite, a high-pressure form of silica, has been produced. It was anicipated that new semiconductors, superconductors, and dielectrics would emerge from high-pressure research.[32]

Ultra-thin silicon wafers, 200 microns in thickness, for impregnated circuits, were cut with a circular phosphor-bronze blade 0.0008 inch thick with an internal cutting edge coated with 325-mesh natural diamond. The blade, held rigid in a clamp, turned at 3,800 rpm and sliced 40 wafers per hour from a 1 1/16-inch bar of silicon. Blade life was estimated at 1,500 wafers.[33]

A metal bonded diamond grinding wheel with two layers of different sized grit was developed in England. In use, the coarse and fine grits alternately contacted the material, and the penetration was greater than with a uniform grit size.[34]

Manufactured diamond is more friable than natural diamond and in use has a tendency to present new sharp cutting edges. When used in resinoid bonded wheels, the irregular shape and rough surface of manufactured diamond provided better mechanical support in the bond and had less diamond loss while grinding. These properties permitted a reduced grinding cost on solid carbide tools.[35]

Large size (60 to 100 mesh) manufactured diamond grit could be used in resinoid bonds for heavy carbide grinding operations. Impact strength of the grit was found to be dependent on bond strength with relation to effect on grinding efficiency. Results indicated that the intermediate shape between blocky and plate-like provided the greatest efficiency. Several tables showing efficiency under different conditions were compiled.[36]

A matched set of two formed diamond dressing wheels were designed and used instead of crusher rolls to dress grinding wheels used in finishing the final drive sprockets for the Army's M–60–A1 tank. The dressing time was from 10 minutes with crush form dressing to 3 minutes with the diamond dressing wheels.[37]

Further progress was made in tailoring diamond crystals during manufacture so that the right combination of shape, size, surface characteristics, and friability would be realized. Techniques were developed for defining quantitatively the shape characteristics of diamond grit. Four basic shapes were recognized: (1) cube shaped particles, (2) blocky particles with no dimension as much as twice that of any other dimension, (3) elongated particles whose largest dimension was two to three times that of either of the other dimensions, and (4) needles with the longest dimension at least three times as great as any other. Flats grouped with needles have a length at least four times the thickness. The average particle shape or shape count was determined by observing 100 particles under a stereomicroscope and assigning the appropriate numerical value to each. The development of improvements in manufacture and in classification of crystal types continued to make manufactured diamond more desirable than natural industrial diamond for some uses.

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[32] Industrial Diamond Review. Ultra High Pressures: A New Dimension in Science. V. 24, No. 281, Apr. 1964, pp. 93–95.

[33] Industrial Diamond Review. Ultra-Thin Silicon Wafers for Impregnated Circuits. V. 24, No. 288, Nov. 1964, p. 269.

[34] Grinding and Finishing. Twin-Layer Diamond Wheels Cut Faster. V. 10, No. 10, Oct. 1964, p. 24.

[35] Grinding and Finishing. Manufactured Diamond Cuts Grinding Cost. V. 10, No. 8, Aug. 1964, pp. 37–38.

[36] Dyer, H. B., and A. R. Roy. Large Synthetic Diamond Grit for Resinoid Bonds. Grinding and Finishing, v. 10, No. 2, Feb. 1964, pp. 25–28.

[37] Gibson, W. L. Form Dressing Time Reduced 70 Percent. Grinding and Finishing, v. 10, No. 1, Jan. 1964, pp. 21–23.

A process was patented for the production of manufactured diamond wherein a greater proportion of coarse and blocky crystals were formed. A carbon-solvent mixture was held for an optimum period at high temperature and high pressure, after which the temperature and then the pressure were decreased.[38]

A method for growing diamond from a seed crystal was proposed. A solution of carbon in a molten metal was circulated from a hot zone to a cooler zone containing a seed diamond. The solution saturated with graphite in the hot zone entered the cool zone where the solubility limit of diamond was exceeded. Growth of the seed diamond was promoted.[39]

Processes were patented for introducing aluminum and boron atoms into diamond crystals to produce electrically conductive diamonds. High pressure and temperature, in the presence of an activator material, were required.[40] A method was announced for producing diamond coated with a film of radioactive metal that rendered the diamond nonretentive charges of static electricity.[41]

X-ray pictures of diamonds formed from graphite in three meteorites were compared with pictures of diamond formed by gravitational pressure within the earth and with similar pictures of manufactured diamond formed by shock similar to that which supposedly formed the diamond in meteorites. It was concluded that since the pictures of meteorite diamond and manufactured diamond showed the same preferred orientation and differed from that of diamond formed in the earth, the meteorite diamond was formed by preterrestrial shock probably occurring during breakup of the meteorite's parent body.[42]

Tests with a microtome indicated that ultrasharp diamond knives offer good possibilities for producing surfaces with microinch accuracy directly by continuous operations. This technique was successfully applied to the cylindrical turning, spherical turning, and facing operations on a number of metals such as aluminum, copper, and nickel. Studies were underway to optimize the geometry of diamond knives for cutting materials other than those that have good ductility.[43]

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[38] Custers, J. F. H., B. W. Senior, H. B. Dyer, and P. T. Wedepohl (assigned to Adamant Laboratories (Prop.) Ltd.). Synthesis of Diamonds. U.S. Pat. 3,124,422, Mar. 10, 1964.

[39] Brinkman, J. A., C. J. Meecham, and H. M. Dieckamp (assigned to North American Aviation, Inc.). Method for Artificial Synthesis of Diamonds. U.S. Pat. 3,142,539, July 28, 1964.

[40] Cannon, P. (assigned to General Electric Corp., Schenectady, N.Y.). Method for and Product Produced by the Introduction of Aluminum Atoms Into the Surface of Diamond Crystals. U.S. Pat. 3,134,739, May 26, 1964.

Wentorf, R. H., Jr. (assigned to General Electric Co., Schenectady, N.Y.). Method for and Product Produced by the Introductions of Boron Atoms Into the Surface of Diamond Crystals. U.S. Pat. 3,141,855, July 21, 1964.

Wentorf, R. H., Jr., and H. P. Bovernkerk (assigned to General Electric Co., Schenectady, N.Y.). Method for the Introduction of Boron Atoms Into Diamond Crystals. U.S. Pat. 3,148,161, Sept. 8, 1964.

[41] Wentorf, R. H., Sr. (assigned to General Electric Co., Schenectday, N.Y.). Radioactive Diamond Composition. U.S. Pat. 3,125,418, Mar. 17, 1964.

[42] Chemistry. Diamonds From Outer Space. V. 37, No. 8, Aug. 1964, pp. 26–27.

The spillway of Navajo Dam near Bloomfield, N. Mex., was smoothed using a bump cutter with 120 natural diamonds mounted on a shaft. The smooth surface minimizes water vibration which would eventually destroy the surface.[44]

Diamond concentrate was immersed in an aqueous solution of sodium silicate to improve the wettability with grease.[45]

The generally accepted explanation of the emplacement of kimberlite has been that an explosion in the crust of the earth either preceded or occurred simultaneously with the eruption which formed the vents now filled with kimberlite. A recent more plausible explanation suggests that the intrusion of kimberlite took place in four phases instead of the one phase formerly theorized. During the first phase, hot magma ascended into the upper crust of the earth and produced some metamorphic effects. The second phase occured when gasses found an outlet to the surface. The resultant release of pressure slowed or ended the upward movement of material in the dikes of the first phase. In the third phase, the upsurge of hot magma within the pipes took place, metamorphosing some of the inclusions. The final phase was the injection of material rich in carbonate and often containing magnetite rather than ilmenite as the chief accessory mineral.[46]

The author of a recently published article suggests that when searching for new areas of kimberlite intrustion, the following should be observed: Prospecting should be carried out in unwarped or horstblock areas, and preferably along tectonic zones already delineated by the more easily recognizable alkaline and carbonate complexes. The Precambrian terrain of Ontario between Lake Superior and James Bay appears to be in accordance with the above features. Possibly the kimberlites in this area are the source of diamonds found in the glacial deposits of Michigan and Wisconsin.[47]

An automatic rough diamond sorting machine for separating all sizes of diamonds from 0.8 to 8.0 mm in size from gangue material concentrated with the diamonds by gravity processes was reported to have been developed. X-rays were used in sorting diamonds impervious to natural light.[48]

ARTIFICIAL ABRASIVES

Industry Review.—The 4-year trend for decreased production of silicon carbide in the United States and Canada was broken when 1964 production was 22,500 tons greater than in 1963. Production of crude aluminum oxide also increased in 1964 following withdrawals from stock in 1963. Most nonmetallic artificial abrasives are manufactured in Canada and processed in the United States. Some abrasive grain is returned to Canada for use in grinding wheels and other abrasive products. Silicon carbide production was at 86 percent of capacity; aluminum oxide at 57 percent; and metallic abrasives at 40 percent. Nonabrasive uses accounted for 5 percent of the aluminum oxide and for 44 percent of the silicon carbide.

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[43] U.S. Department of Commerce, Office of Technical Services. Successful Use of Diamond Knives in Precision Turning. Special Announcement, Oct. 13, 1964, 2 pp.

[44] International Science and Technology. No. 34, Oct. 1964, p. 54.

[45] Jakoutalmase, T. French Pat. 1,354,261. Jan. 27, 1964.

[46] South African Mining and Engineering Journal (Johannesburg). Recent Advances in Diamond Practice and Theory. V. 75, pt. 2, No. 3728, May 17, 1964, pp. 343, 344, 349, 353.

[47] Dawson, J. B. An Aid to Prospecting for Kimberlites. Econ. Geol., v. 59, No. 7, Nov. 1964, pp. 1385–1386.

[48] World Mining. Automatic, Rough Diamond Sorter Based on Certain X-Rays. V. 17, No. 13, Dec. 1964, p. 49.

Sales of coated abrasives totaled 2,603,761 reams valued at $140,477,968, an increase of 7 percent in quantity and 9 percent in value compared with sales in 1963. Aluminum oxide accounted for 42 percent of the total reams sold; silicon carbide, 33 percent; garnet, 13 percent; flint, 9 percent; and emery and crocus, 3 percent. Glue bond was used on 55 percent of the coated abrasives; waterproof bonds on 23 percent; and resin bonds on 22 percent.

TABLE 13.—Crude artificial abrasives produced in the United States and Canada

Year	Silicon carbide [1]		Aluminum oxide [1] (abrasive grade)		Metallic abrasives [2]		Total	
	Short tons	Value (thousands)	Short tons	Value (thousands)	Short tons	Value (thousands)	Short tons	Value (thousands)
1955–59 (average)	107,637	$16,940	180,164	$22,368	131,490	$17,520	419,291	$56,828
1960	133,219	20,636	195,906	27,111	112,383	16,847	441,508	64,594
1961	125,726	20,078	136,951	18,735	109,515	16,124	372,192	54,937
1962	115,716	17,728	181,924	23,458	125,772	18,668	423,412	59,854
1963	109,351	15,530	160,064	20,936	133,408	20,057	402,823	56,523
1964	131,905	18,432	171,462	21,493	155,802	23,445	459,169	63,370

[1] Figures include material used for refractories and other nonabrasive purposes.
[2] Shipments from U.S. plants only.

TABLE 14.—Production, shipments, and stocks of metallic abrasives in the United States, by products

Year and product	Manufactured		Sold or used		Stocks Dec. 31 (short tons)	Annual capacity (short tons)
	Short tons	Value (thousands)	Short tons	Value (thousands)		
1963:						
Chilled iron shot and grit	36,895	$3,965	39,228	$4,625	9,199	253,658
Annealed iron shot and grit	33,682	3,948	32,384	3,985	1,531	[1] 91,574
Steel shot and grit	58,675	9,628	60,105	10,834	8,511	118,550
Other [2]	1,672	607	1,691	613		8,310
Total	130,924	18,148	133,408	20,057	[3] 19,241	380,518
1964:						
Chilled iron shot and grit	40,823	4,407	40,470	4,618	9,552	253,438
Annealed iron shot and grit	35,710	4,028	35,541	4,199	1,700	[1] 101,894
Steel shot and grit	76,921	12,727	77,866	14,037	7,071	122,850
Other [2]	2,177	638	1,925	592	747	9,700
Total	155,631	21,800	155,802	23,446	19,070	385,988

[1] Included in capacity of chilled iron shot and grit.
[2] Includes cut wire shot.
[3] Includes revisions in product detail.

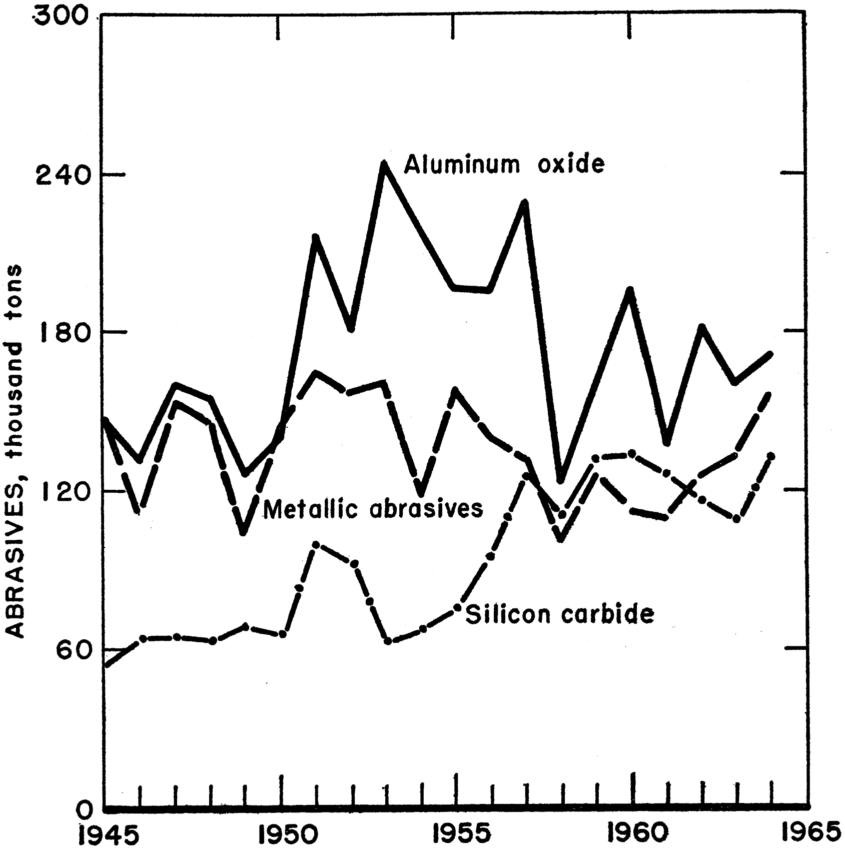

FIGURE 1.—Artificial abrasives production.

TABLE 15.—Stocks of crude artificial abrasives and capacity of manufacturing plants, as reported by producers in the United States and Canada

(Thousand short tons)

Year	Silicon carbide		Aluminum oxide		Metallic abrasives [1]	
	Stocks Dec. 31	Annual capacity	Stocks Dec. 31	Annual capacity	Stocks Dec. 31	Annual capacity
1955-59 (average)	11.3	130.7	36.2	292.7	16.3	256.1
1960	16.0	145.6	25.1	299.5	15.6	263.1
1961	14.7	145.7	23.2	299.5	18.6	265.4
1962	19.2	144.9	33.8	299.5	21.2	363.9
1963	11.2	146.5	20.6	303.4	r 19.2	380.5
1964	15.0	152.5	14.5	298.8	19.1	386.0

r Revised.

[1] United States only.

Technology.—A method was developed for coating aluminum oxide grinding wheels to make them conductive and useful for electrolytically assisted grinding. The whole wheel can be made conductive, allowing stress free grinding and eliminating any damage to the workpiece. The method used the wheel as cathode, the workpiece as anode, and the coolant as electrolyte.[49]

Nonwoven washable nylon pads surfaced with very fine silicon carbide were added to the many industrial abrasives. They were reported to conform to contours and to be useful in corrosion removal of many metals and for satin finishing aluminum.[50]

A new edition of American Standard Safety Code for the Use, Care, and Protection of Abrasive Wheels was released. The code has been incorporated into the law of several States. Copies of the revised code, B7.1–1964, were being distributed by Grinding Wheel Institute and by grinding wheel manufacturers.

A method was announced for making extremely hard, partially resolidified silicon carbide useful in manufacturing high-quality cutting and abrading tools.[51] Research on the effect of crystal orientation on hardness of silicon carbide indicated that the difference in average hardness was almost 40 percent between the hardest and softest directions in the crystals.[52]

A new apparatus developed at Osaka University, Japan, permitted observation of the behavior of abrasive grain during grinding. It was found that the grains were not self-dressing during grinding and that one mechanism of grain wear was caused by sliding of the cutting edges.[53]

The concept of grinding as a primary metal removal process received considerable attention. The advantages of this process over traditional metal cutting processes for many types of work were emphasized. Among advantages were fast rate of metal removal, fast setup, small quantity of heat generated, and reduction in material waste.[54] A series of articles emphasized the effectiveness of abrasive machining, the development of a large grinder to handle plates, weldments, and castings up to 80 inches wide, 72 inches high, and 180 inches long. Some of today's grinders removed 600 pounds of metal per hour. In 1950 hand operated swing crane grinders might have taken almost 12 hours to remove the same quantity of metal. Powerful motors and deep cuts with decreased heat generation were being emphasized.[55]

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[49] Industrial Research Newsletter (IIT Research Institute, Chicago, Ill.). Method for Coating Aluminum Oxide Grinding Wheels. Nov. 1964, p. 1.

[50] Iron Age. Nylon Abrasives. V. 194, No. 9, Aug. 27, 1964, p. 157.

[51] Hall, H. T. (assigned to Research Corp., New York, N.Y.). Method of Making High Compressive Strength Silicon Carbide and the Product Thereof. U.S. Pat. 3,158,442, Nov. 24, 1964.

[52] Shaffer, Peter T. B. Effect of Crystal Orientation on Hardness of Silicon Carbide. J. Am. Ceram. Soc., v. 47, No. 9, Sept. 21, 1964, p. 466.

[53] Iron Age. Watch Grinding Action. V. 193, No. 18, Apr. 30, 1964, p. 15.

[54] Nisula, George. Remove Metal at Lower Cost by Abrasive Machining. Product Eng., v. 35, No. 11, May 25, 1964, pp. 106–109.

[55] Eshelman, R. H. Abrasive Machining Goes Big. Iron Age, v. 193, No. 9, Feb. 27, 1964, p. 55.

———. Abrasive Machining: The Big Bite of Tiny Grains. Iron Age, v. 193, No. 15, Apr. 9, 1964, pp. 93–100.

Iron Age. Abrasives Take Big Cuts. V. 193, No. 13, Mar. 26, 1964, p. 15.

Rohan, T. M. Take Heavier Cut, Abrasive Users Told. Iron Age, v. 193, No. 13, Mar. 26, 1964, p. 70.

The three dependent variables of an abrasive selected for a desired finish, cycle time, abrasive consumption, and maintenance cost were discussed for the metal abrasives cast iron, cast steel, and cut wire. Several conclusions were presented: (1) The smaller the abrasive size, the finer the finish; (2) the smaller the abrasive size, the less the impact; (3) the harder the abrasive, the faster the cleaning; and (4) the harder the abrasive, the more etched the finish.[56]

Impeller blades and housing of a fan used to move garnet dust were covered with 1/8 inch of urethane. Uncovered metal lasted as little as 3 months. The urethane coating showed little wear after being in service almost a year.[57]

MISCELLANEOUS MINERAL-ABRASIVE MATERIALS

In addition to the natural and artificial abrasive materials for which data are available, many other minerals were used for abrasive purposes. Oxides of tin, magnesium, iron, and cerium were used for polishing. Boron carbide and tungsten carbide were used as abrasives where extreme hardness was required. Finely ground and calcined clays, lime, talc, ground feldspar, river silt, slate flour, whiting, and other materials also were used as abrasives.

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[56] Frank, L. C. Further Comments on . . . Selecting an Abrasive. Foundry, v. 92, No. 2, Feb. 1964, pp. 111–112, 114.

[57] Engineering and Mining Journal. Cast Urethane Linings Reduce Blade Wear at Garnet Plant. V. 165, No. 5, May 1964, p. 117.

Aluminum

By John W. Stamper[1]

◆

EXPANSION and growth of the aluminum industry continued in 1964, and the trend toward greater emphasis on international aspects intensified. World production of primary metal reached a new record of 6.7 million tons, 11 percent higher than that of 1963. Domestic output also increased to a new record of nearly 2.6 million tons, a 10-percent increase. Reflecting the strong demand, the average price for primary aluminum increased by 5 percent over the 1963 average.

TABLE 1.—Salient aluminum statistics

(Thousand short tons and thousand dollars)

	1955-59 (average)	1960	1961	1962	1963	1964
United States:						
Primary production	1,682	2,014	1,904	2,118	2,313	2,553
Value	$811,113	$1,030,007	$949,768	$998,559	$1,039,812	$1,196,013
Price: Ingot, average cents per pound	26.2	26.0	25.5	23.9	22.6	23.7
Secondary recovery [1]	338	329	340	462	506	552
Imports for consumption (crude and semicrude)	271	196	255	377	466	453
Exports (crude and semicrude)	82	384	238	259	292	349
Consumption, apparent [2]	2,191	2,016	2,320	r 2,770	r 3,040	3,216
World: Production	3,855	4,950	5,185	5,580	6,080	6,730

r Revised.

[1] By reporting companies, aluminum content.

[2] Measured by quantity of primary sold or used plus secondary recovery and net imports.

LEGISLATION AND GOVERNMENT PROGRAMS

Under a 2-year program to dispose of 135,000 tons of aluminum metal from the Defense Production Act (DPA) inventory, the Government sold 49,000 tons in 1964 at an average value of 23.9 cents per pound. Of the 35,000 tons remaining to be sold under the program, 25,000 tons represented the total quantity restricted for small firms, none of which has been sold.

The quantity of aluminum metal in the national (strategic) stockpile was 1,128,988 short tons. An additional 796,892 short tons was in the DPA inventory.

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[1] Commodity specialist, Division of Minerals.

DOMESTIC PRODUCTION

PRIMARY

Domestic production of primary aluminum ingot reached a new peak for the third successive year, exceeding output in 1963 by 9 percent or 200,000 short tons. Total output was virtually 100 percent of the industry's rated capacity at the end of the year.

Aluminium Ltd. of Canada, the second largest producer of primary aluminum in North America, announced that it would purchase the interests of Bridgeport Brass Co., Division of National Distillers & Chemical Corp., Cerro Corp., and Scovill Manufacturing Co., in the 100,000-ton-per-year aluminum hot-rolling mill at Oswego, N.Y., operated by Alroll Inc. Aluminium, which already owned 50.1 percent of Alroll, also planned to acquire Bridgeport's facilities in Warren, Ohio, Riverside, Calif., and South Kearny, N.J., having an annual capacity of about 50,000 tons of aluminum sheet products and forgings, and Cerro's plants in Fairmont, W. Va., and Los Angeles, Calif., having about the same capacity. The acquisitions, with other plants already owned, reportedly will make Aluminium the fourth largest aluminum semifabricator in the United States.

TABLE 2.—Production and shipments of primary aluminum in the United States [1]

(Short tons)

Quarter	1963		1964	
	Production	Shipments	Production	Shipments
First	528,725	549,279	626,418	619,465
Second	566,688	602,935	626,680	645,665
Third	601,807	591,335	644,612	621,675
Fourth	[r] 615,308	[r] 610,075	655,037	668,093
Total	[r] 2,312,528	[r] 2,353,624	2,552,747	2,554,898

[r] Revised.

[1] Quarterly production and shipments adjusted to final annual totals.

Aluminum Company of America completed installation of its new 52,000-ton-per-year aluminum smelter at Badin, N.C., which replaced the older 47,150-ton plant, formerly operated at the same location, and resumed construction of a second 35,000-ton-per-year potline at Warwick, Ind. The company also began production from the first of two 60,000-ton-per-year, light-gage, cold-rolling mills at Warwick and scheduled completion of the second mill and a hot mill to produce aluminum reroll stock in 1965.

Reynolds Metals Co. embarked upon a special 4-year, $140 million program of plant additions and improvements to cut operating costs and increase production capabilities to keep pace with market growth. No new aluminum smelters were planned, but primary aluminum capacity was expected to be increased about 12 percent to 815,000 tons per year by 1967. Appropriate increases in mining, alumina, and fabricating facilities also were scheduled for completion in the 1964 to 1968 period. Capacities of the company's aluminum smelters at Longview, Wash., Listerhill, Ala., and Massena, N.Y., were revised upward during the year. Single potlines were rebuilt at plants at Troutdale, Oreg., and Jones Mills, Ark.

TABLE 3.—Aluminum production capacity in the United States, by companies

(Short tons per year)

Company and plant	Capacity: Actual, end of 1964	Capacity: Being built in 1964	Capacity: Total, actual and under construction
Aluminum Company of America:			
Alcoa, Tenn.	157,100		157,100
Badin, N.C.	52,000		52,000
Evansville, Ind.	35,000	140,000	175,000
Massena, N.Y.	118,000	32,000	150,000
Point Comfort, Tex.	140,000		140,000
Rockdale, Tex.	150,000		150,000
Vancouver, Wash.	97,500		97,500
Wenatchee, Wash.	108,500		108,500
Total	858,100	172,000	1,030,100
Reynolds Metals Co.:			
Arkadelphia, Ark.	55,000		55,000
Jones Mills, Ark.	109,000		109,000
Listerhill, Ala.	194,500		194,500
Longview, Wash.	65,000		65,000
Massena, N.Y.	115,000		115,000
San Patricio, Tex.	95,000		95,000
Troutdale, Oreg.	91,500		91,500
Total	725,000		725,000
Kaiser Aluminum & Chemical Corp.:			
Chalmette, La.	247,500		247,500
Mead, Wash.	176,000		176,000
Ravenswood, W. Va.	145,000		145,000
Tacoma, Wash.	41,000		41,000
Total	609,500		609,500
Anaconda Aluminum Co.: Columbia Falls, Mont.	67,500	32,500	100,000
Consolidated Aluminum Corp.: New Johnsonville, Tenn.	32,000	30,000	62,000
Harvey Aluminum, Inc.: The Dalles, Oreg.	87,000		87,000
Ormet Corp.: Hannibal, Ohio	180,000		180,000
Intalco Aluminum Corp.: Bellingham, Wash.		76,000	76,000
Grand total	2,559,100	310,500	2,869,600

Kaiser Aluminum & Chemical Corp. reactivated its aluminum smelter at Tacoma, Wash., late in the year. The 41,000-ton-per-year facility had been idle since 1958 and efficiency was expected to be greatly improved. The company acquired the assets of Standard Magnesium & Chemical Co., a large secondary magnesium smelter with extruding and fabricating capability and magnesium melting flux operations in Tulsa, Okla. The largest single use of magnesium is in aluminum alloys.

Intalco Aluminum Corp., owned 50 percent by American Metal Climax, Inc. and 25 percent each by Péchiney Enterprises Inc. (a U.S. subsidiary of Péchiney Compagnie de Produits Chimiques et Électrométallurgiques of France), and Howe Sound Co., began construction of a 76,000-ton-per-year aluminum smelter at Bellingham, Wash. Production of primary aluminum was expected during the first half of 1966. Péchiney, which also owned 40 percent of Howe Sound Co., is providing process engineering for construction and operation of the facilities.

In midyear Consolidated Aluminum Corp., a fully owned subsidiary of Swiss Aluminum Ltd. of Zurich, Switzerland, completed expansion of its 20,000-ton-per-year aluminum smelter to 32,000 tons per year and had nearly completed a new potline to increase annual capacity to 62,000 tons.

As part of a long-range program to produce aluminum items, Phelps Dodge Aluminum Corp., owned by the Phelps Dodge Corp., acquired an aluminum extrusion plant at Murphysboro, Ill., an aluminum rod mill at Columbia, Tenn., an alloy rod and wire plant at Florence, Ala., and a wire screening plant at Covington, Ga. The facilities were enlarged and improved during the year. Investment in the newly acquired plants was expected to total $11.5 million. In 1963 Phelps Dodge negotiated long-term agreements with N. V. Billiton Maatschappij, a producer of bauxite in Surinam, and Consolidated Aluminum Corp. for an assured supply of 30,000 tons of primary aluminum per year.

The Anaconda Aluminum Co. continued construction of a third potline at Columbia Falls, Mont., to raise its annual aluminum capacity to 100,000 tons by late 1965.

SECONDARY

The secondary aluminum industry had its best year on record, recovering 552,000 tons or about 46,000 tons more aluminum metal than in 1963. According to reports received by the Bureau of Mines, domestic recovery of aluminum alloys (including all constituents) from aluminum-base scrap totaled 595,000 tons. Metallic recovery from new scrap was 454,985 tons, an increase of 10 percent. Recovery from old scrap and sweated pig increased to 140,000 tons. An additional 1,230 tons of aluminum was recovered from copper-, zinc-, and magnesium-base scrap. The value of 550,461 tons of aluminum recovered from processed aluminum scrap was $260 million, computed from the average price of primary aluminum ingot of 23.7 cents per pound.

Purchased aluminum-base scrap and sweated pig reported used by all consumers totaled 712,000 tons. Independent secondary smelters used 539,000 tons, or 76 percent. Primary producers used 59,000 tons, or 8 percent; fabricators used 64,000 tons, or 9 percent; and foundries and other consumers used 50,000 tons, or 7 percent.

The Bureau of Mines estimated that complete coverage of the industry would show a total scrap consumption of 850,000 tons and a secondary ingot production of 553,000 tons. Calculated aluminum recovery based on full coverage would total 657,000 tons, and the metallic aluminum-alloy recovery would total 707,000 tons.

Secondary aluminum-alloy ingot production, as reported to the Bureau of Mines, totaled 472,000 tons, 8 percent more than in 1963. Data on remelt ingots excluded alloys produced from purchased scrap by the primary producers. Shipments of most casting alloys increased in 1963.

Data obtained through a Bureau canvass were combined with data made available to the Bureau by the Aluminum Smelters Research Institute, which covered operations of its members. The combined coverage was estimated to represent about 85 percent of the secondary aluminum smelter industry.

TABLE 4.—Aluminum recovered from scrap processed in the United States, by kind of scrap and form of recovery

(Short tons)

Kind of scrap	1963	1964	Form of recovery	1963	1964
New scrap:					
Aluminum-base	[1] 389,263	[2] 427,518	As metal	25,114	24,130
Copper-base	56	67	Aluminum alloys	469,337	513,328
Zinc-base	131	150	In brass and bronze	538	1,945
Magnesium-base	220	279	In zinc-base alloys	5,121	6,292
			In magnesium alloys	1,636	1,522
Total	389,670	428,014	In chemical compounds	3,845	4,474
Old scrap:			Total	505,591	551,691
Aluminum-base	[1] 115,164	[2] 122,943			
Copper-base	76	98			
Zinc-base	436	450			
Magnesium-base	245	186			
Total	115,921	123,677			
Grand total	505,591	551,691			

[1] Aluminum alloys recovered from aluminum-base scrap in 1963, including all constituents, were 413,174 tons from new scrap and 131,325 tons from old scrap and sweated pig; total 544,499 tons.

[2] Aluminum alloys recovered from aluminum-base scrap in 1964 including all constituents, were 454,985 tons from new scrap and 140,150 tons from old scrap and sweated pig; total 595,135 tons.

In September Chrysler Corp. disclosed that it was making production runs at its Kokomo, Ind., casting plant using molten aluminum transported directly from a secondary smelter. Wabash Smelting, Inc., ships the molten metal from its smelter at Wabash, Ind., some 40 miles from Kokomo, in 1,500-pound insulated ladles.

The U.S. Reduction Co., a major secondary aluminum smelter, acquired full ownership of Master Alloys, Inc., a producer of aluminum-based master alloys at Russellville, Ala. Master Alloys, Inc., was formed in 1963 by U.S. Reduction Company and Howe Sound Co. as joint owners. Alloys & Chemicals Corp., planned to expand its facilities at Cleveland, Ohio, to provide more capacity to produce secondary aluminum alloys and permit the company to use lower grade scrap. In 1963 Alloys & Chemicals Corp. acquired a 50-percent interest in Cuyahoga Smelting & Processing Co. facilities in Cleveland, reportedly to increase its capabilites for handling aluminum drosses and skimmings. The Pyrites Co., Inc., a wholly owned subsidiary of Rio Tinto Zinc Corp., Ltd., reportedly planned to acquire the assets of Alloys & Chemical Corp. An installation to recover aluminum from slag and dross was completed at the Apex Smelting Co., Division of American Metal Climax, Inc., facilities in Cleveland, Ohio.

TABLE 5.—Stocks and consumption of new and old aluminum scrap and sweated pig in the United States in 1964[1]

(Short tons)

Class of consumer and type of scrap	Stocks, Jan. 1 [r]	Receipts	Consumption			Stocks, Dec. 31
			New scrap	Old scrap	Total	
Secondary smelters:[2]						
New scrap:						
Segregated 2S sheet and clips	557	7,545	7,643	----------	7,643	459
Segregated 3S sheet and clips	649	11,302	11,600	----------	11,600	351
Segregated 51S, 52S, 61S, etc., sheet and clips, less than 0.6 percent Cu	2,330	32,049	32,722	----------	32,722	1,657
Segregated 14S, 17S, 24S, 25S, etc., sheet and clips, more than 0.6 percent Cu	597	13,018	13,394	----------	13,394	221
Segregated 75S, 76S, 77S, 78S, 80S sheet and clips, more than 0.6 percent Cu	421	8,906	8,819	----------	8,819	508
Mixed low Cu clips, 0.6 percent maximum Cu	2,384	44,070	44,272	----------	44,272	2,182
Mixed clips, more than 0.6 percent Cu	2,001	41,232	42,004	----------	42,004	1,229
Cast scrap	449	6,854	7,048	----------	7,048	255
Borings and turnings:						
Segregated 14S, 17S, 24S, 25S	369	14,192	14,257	----------	14,257	304
Segregated 75S, 76S, 77S, 78S, 80S	413	14,178	14,442	----------	14,442	149
Segregated other	1,005	23,172	23,807	----------	23,807	370
Mixed, Zn 1.0 percent maximum	1,011	32,949	32,402	----------	32,402	1,558
Mixed, Zn over 1.0 percent	1,777	49,814	50,303	----------	50,303	1,288
Dross and skimmings	6,310	80,251	80,067	----------	80,067	6,494
Foil (includes both new and old)	398	3,092	3,148	----------	3,148	342
Miscellaneous	930	10,421	10,502	----------	10,502	849
Old scrap:						
Wire and cable	443	2,288	----------	2,306	2,306	425
Pots and pans	1,018	24,478	----------	24,364	24,364	1,132
Mixed alloy sheet	630	9,666	----------	9,790	9,790	506
Aircraft	167	4,218	----------	4,232	4,232	153
Castings and forgings	1,027	30,283	----------	30,179	30,179	1,131
Pistons	174	3,617	----------	3,645	3,645	146
Irony aluminum	918	17,316	----------	16,771	16,771	1,463
Miscellaneous	1,633	9,405	----------	9,305	9,305	1,733
Purchased pig	4,653	42,005	----------	41,970	41,970	4,688
Total	32,264	536,321	396,430	142,562	538,992	29,593
Foundries, fabricators, and chemical plants:						
New scrap:						
Segregated 2S sheet and clips	239	7,915	7,997	----------	7,997	157
Segregated 3S sheet and clips	2,208	21,672	23,708	----------	23,708	172
Segregated 51S, 52S, 61S, etc., sheet and clips, less than 0.6 percent Cu	415	17,210	17,161	----------	17,161	464
Segregated 75S, 76S, 77S, 78S, 80S sheet and clips, more than 0.6 percent Cu	83	2,163	2,128	----------	2,128	118
Mixed low Cu clips, 0.6 percent maximum Cu	340	9,582	9,268	----------	9,268	654
Mixed clips, more than 0.6 percent Cu	349	3,020	3,180	----------	3,180	189
Cast scrap	----------	1,589	1,584	----------	1,584	5
Borings and turnings:						
Segregated 75S, 76S, 77S, 80S	----------	49	49	----------	49	----------
Segregated other	1	----------	1	----------	1	----------
Mixed, Zn 1.0 percent maximum	267	1,269	1,347	----------	1,347	189
Dross and skimmings	314	3,221	3,431	----------	3,431	104
Foil (includes both new and old)	831	2,133	2,409	----------	2,409	555
Miscellaneous	580	19,827	20,090	----------	20,090	317
Old scrap:						
Wire and cable	161	1,667	----------	1,770	1,770	58
Pots and pans	----------	10	----------	9	9	1
Mixed alloy sheet	----------	63	----------	61	61	2
Aircraft	----------	26	----------	25	25	1
Castings and forgings	58	601	----------	609	609	50
Pistons	1	59	----------	58	58	2
Irony aluminum	36	622	----------	632	632	26
Miscellaneous	2	243	----------	237	237	8
Purchased pig	2,141	19,086	----------	18,577	18,577	2,650
Total	8,026	112,027	92,353	21,978	114,331	5,722

See footnotes at end of table.

TABLE 5.—Stocks and consumption of new and old aluminum scrap and sweated pig in the United States in 1964 [1]—Continued

Class of consumer and type of scrap	Stocks, Jan. 1 [r]	Receipts	Consumption			Stocks, Dec. 31
			New scrap	Old scrap	Total	
Primary producers:						
New scrap:						
Segregated 2S sheet and clips	41	2,642	2,599	----------	2,599	84
Segregated 3S sheet and clips	169	7,096	7,074	----------	7,074	191
Segregated 51S, 52S, 61S, etc., sheet and clips, less than 0.6 percent Cu	743	24,475	21,227	----------	21,227	3,991
Segregated 14S, 17S, 24S, 25S, etc., sheet and clips, more than 0.6 percent Cu	25	1,229	1,177	----------	1,177	77
Segregated 75S, 76S, 77S, 78S, 80S type sheet and clips, more than 0.6 percent Cu	7	551	502	----------	502	56
Mixed low Cu clips—0.6 percent maximum Cu	33	2,655	2,227	----------	2,227	461
Mixed clips, more than 0.6 percent Cu	----------	13	13	----------	13	----------
Cast scrap	64	11,581	11,402	----------	11,402	243
Borings and turnings:						
Segregated 14S, 17S, 24S, 25S	17	19	35	----------	35	1
Segregated other	6	307	272	----------	272	41
Mixed, Zn 1.0 percent maximum	----------	8	8	----------	8	----------
Dross and skimmings	30	36	66	----------	66	----------
Foil (includes both new and old)	----------	4,147	4,037	----------	4,037	110
Miscellaneous	202	8,132	7,555	----------	7,555	779
Old scrap:						
Wire and cable	8	809	----------	729	729	88
Miscellaneous	----------	5	----------	5	5	----------
Total	1,345	63,705	58,194	734	58,928	6,122
Total of all scrap consumed:						
New scrap:						
Segregated 2S sheet and clips	837	18,102	18,239	----------	18,239	700
Segregated 3S sheet and clips	3,026	40,070	42,382	----------	42,382	714
Segregated 51S, 52S, 61S, etc., sheet and clips, less than 0.6 percent Cu	3,488	73,734	71,110	----------	71,110	6,112
Segregated 14S, 17S, 24S, 25S, etc., sheet and clips, more than 0.6 percent Cu	622	14,247	14,571	----------	14,571	298
Segregated 75S, 76S, 77S, 78S, 80S sheet and clips, more than 0.6 percent Cu	511	11,620	11,449	----------	11,449	682
Mixed low Cu clips, 0.6 percent maximum Cu	2,757	56,307	55,767	----------	55,767	3,297
Mixed clips, more than 0.6 percent Cu	2,350	44,265	45,197	----------	45,197	1,418
Cast scrap	513	20,024	20,034	----------	20,034	503
Borings and turnings:						
Segregated 14S, 17S, 24S, 25S	386	14,211	14,292	----------	14,292	305
Segregated 75S, 76S, 77S, 78S, 80S	413	14,227	14,491	----------	14,491	149
Segregated other	1,012	23,479	24,080	----------	24,080	411
Mixed, Zn 1.0 percent maximum	1,278	34,226	33,757	----------	33,757	1,747
Mixed, Zn over 1.0 percent	1,777	49,814	50,303	----------	50,303	1,288
Dross and skimmings	6,654	83,508	83,564	----------	83,564	6,598
Foil (includes both new and old)	1,229	9,372	9,594	----------	9,594	1,007
Miscellaneous	1,712	38,380	38,147	----------	38,147	1,945
Old scrap:						
Wire and cable	612	4,764	----------	4,805	4,805	571
Pots and pans	1,018	24,488	----------	24,373	24,373	1,133
Mixed alloy sheet	630	9,729	----------	9,851	9,851	508
Aircraft	167	4,244	----------	4,257	4,257	154
Castings and forgings	1,085	30,884	----------	30,788	30,788	1,181
Pistons	175	3,676	----------	3,703	3,703	148
Irony aluminum	954	17,938	----------	17,403	17,403	1,489
Miscellaneous	1,635	9,653	----------	9,547	9,547	1,741
Purchased pig	6,794	61,091	----------	60,547	60,547	7,338
Total	41,635	712,053	546,977	165,274	712,251	41,437

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[r] Revised.

[1] Includes imported scrap.

[2] Excludes secondary smelters owned by primary aluminum companies.

TABLE 6.—Production and shipments of secondary aluminum alloys, by independent smelters

(Short tons)[1]

Product	1963		1964	
	Production[2]	Shipments[3]	Production[2]	Shipments[3]
Pure aluminum (Al minimum, 97.0 percent)	25,114	24,666	24,130	23,382
Aluminum-silicon (maximum Cu. 0.6 percent)				
95/5 Al-Si, 356, etc. (0.6 percent Cu maximum)	19,305	18,533	20,036	20,735
13 percent Si, 360, etc. (0.6 percent Cu maximum)	35,921	35,022	34,786	35,074
Aluminum-silicon (Cu, 0.6 to 2 percent)	8,403	8,209	8,561	8,337
No. 12 and variations	4,714	4,361	6,550	6,677
Aluminum-copper (maximum Si, 1.5 percent)	1,621	1,552	1,945	2,022
No. 319 and variations	48,111	47,456	52,358	53,352
Nos. 122, 138	3,225	3,245	1,757	1,744
AXS-679 and variations	190,367	187,574	219,569	220,116
Aluminum-silicon-copper-nickel	24,857	23,977	24,862	25,307
Deoxidizing and other destructive uses				
Grades 1 and 2	10,086	10,143	10,626	10,932
Grades 3 and 4	14,573	14,630	13,023	13,261
Aluminum-base hardeners	21,699	21,096	15,864	16,480
Aluminum-magnesium	1,636	1,664	1,522	1,564
Aluminum-zinc	5,121	4,913	6,292	6,219
Miscellaneous	22,584	21,683	30,410	30,717
Total	437,337	428,724	472,291	475,919

[1] Gross weight, including copper, silicon, and other alloying elements. Secondary smelters used 10,306 and 11,498 tons of primary aluminum in 1963 and 1964, respectively, in producing pure aluminum and secondary alloys.

[2] No allowance was made for consumption by producing plants.

[3] No allowance was made for receipts by producing plants.

CONSUMPTION AND USES

Primary aluminum sold or used by producers increased almost 9 percent over that of 1963, but the total apparent consumption of aluminum increased by only 6 percent, owing to a sharp decline in net trade.

According to figures compiled by the Aluminum Association from industry estimates, the distribution of shipments of aluminum metal to various industries was as follows: Building and construction, 23.5 percent; transportation, 22.3 percent; consumer durables, 10.7 percent; electrical equipment, 11.7 percent; machinery and equipment, 7.0 percent; containers and packaging, 8.0 percent; and other industries, 8.7 percent. The remainder was exported. The per capita use of aluminum increased from approximately 31 pounds in 1963 to almost 34 pounds. Uses of aluminum in electrical equipment was the fastest growing, increasing almost 20 percent over 1963.

About 500 tons of specially designed aluminum siding was scheduled to be used as the exterior wall of an assembly building destined to become the world's largest structure. The building, which was under construction at the Kennedy Space Center on Merritt Island, Fla., also will require an additional 700 tons of aluminum for flashing, other walls, and duct work.

A dome-shaped building, erected in Jamaica to store dried bauxite, was the largest structure of its kind to be built of aluminum. The aluminum-framed dome, covered with aluminum panels, spanned 300 feet and was built to support 94 tons of equipment and a moving load from the center ring.

TABLE 7.—Apparent consumption of aluminum in the United States

(Short tons)

Year	Primary sold or used by producers[1]	Imports (net)[2]	Recovery from old scrap[3]	Recovery from new scrap[3]	Total apparent consumption
1955–59 (average)	1,664,385	189,351	72,527	264,885	2,191,148
1960	1,866,251	−180,057	62,703	266,747	2,015,644
1961	1,956,167	24,004	102,137	238,109	2,320,417
1962	2,184,876	[r]123,839	[r]128,520	[r]333,236	[r]2,770,471
1963[r]	2,353,624	180,878	115,921	389,670	3,040,093
1964	2,554,898	109,901	123,677	428,014	3,216,490

[r] Revised.

[1] Includes shipments to the Government: 1957, 324,311 tons; 1958, 323,128 tons; 1959, 73,235 tons; 1960, 37,002 tons; 1961, 52,138 tons; 1962, 41,544 tons; 1963, 24,293 tons; 1964, none.

[2] Crude and semicrude. Includes ingot equivalent of scrap imports and exports (weight multiplied by 0.9). Includes some shipments to Government stockpiles: Figures not available.

[3] Aluminum content.

Despite successive gains in recent years industry reports indicated that the average use of aluminum in the 1965 passenger automobiles was about the same as that in the 1964 models, owing chiefly to a decrease in the use of decorative trim. However, the growing interest in aluminum racing engines, wheels, and automobile air-conditioning units indicated that the automobile market will continue to provide an expanding future market for aluminum. A report predicted that the aluminum engine block, which was being used in only one passenger car (Chevrolet's Corvair), would come into wide use before 1970.[2]

It was estimated that one-half of all truck-trailer bodies and two out of five tank trucks were made of aluminum. In the railroad freight and tank car market, it was estimated that in 1962 11,000 tons of aluminum was used in roofs, sides, ends, doors, floors, and in other components. An estimated 14,000 tons was used by the railroad industry in 1963 and 17,000 tons in 1964. Forged aluminum wheels with steel rims were being tested for railroad use.

Aluminum continued as the leading material of construction for small pleasure boats and was used in about 49 percent of the total produced in 1964. Launching of the first aluminum research submarine, construction of a 220-foot hydrofoil built of aluminum, and the use of over 60 tons of aluminum in a naval gunboat foreshadowed an increasing role for the metal in large craft.

More than 6,000 aluminum V-6 engines, originally designed for the 1962 Buick Special automobile, were expected to be used in powering 1965 model boats.

Commercial development of the all-aluminum beer can, an aluminum tear-top lid, and drawn aluminum cans suitable for heat-processed foods, spearheaded aluminum's gains in the packaging industry, a fast growing market for the light metal. Other new uses for aluminum in containers, which gained acceptance during the year, included all-aluminum orange crates, sardine cans, soft drink cans, and a draft beer container for the consumer market.

The improved mechanical properties of aluminum at cryogenic temperatures was used to advantage in a number of applications including a heat exchanger for extracting helium from natural gas that contained some 200 miles of the light metal tubing. Extruded aluminum tubes, 18.5 feet long and weighing over 1,000 pounds, were used to hold helium under high pressure. Four of the tubes will be submersed in liquid oxygen at minus 297° F inside the fuel tanks of the Saturn V launching vehicle to control the flow of the liquid oxygen fuel to the rocket motor.

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[2] Herrman, G. E. Will the Aluminum Engine Come Back? Foundry, v. 92, No. 9, September 1964, pp. 142–143, 145, 148–153.

Uses of aluminum as an electrical conductor continued to expand. The 52 miles of extra high voltage (EHV) transmission lines being installed by the Central Illinois Public Service Co., will use ACSR (aluminum conductor—steel reinforced). This installation also marks the first use of aluminum for EHV H-frame towers. A new type of aluminum cable, ACAR (aluminum conductor—alloy reinforced), was selected for use in the EHV transmission lines which will deliver electric energy to Pennsylvania, New Jersey, Maryland, and Delaware from a huge thermal power generating plant under construction in Pennsylvania. About 3,700 miles of 91 strand cable, nearly 2 inches in diameter and weighing about 25,000 tons, will be required.

Atomized aluminum powder is one of the fuel elements used in most solid rocket fuels because it contributes to the reliability, durability, and ease of handling of such fuels. A new blasting agent based on ammonium nitrate, that contains 5 to 30 percent aluminum in the form of chips, was announced. The new blasting agent, called MS–80, was reportedly more powerful by weight and safer than present formulations.[3]

The following distribution for wrought products was obtained from figures published by the Bureau of the Census.

	Percent	
	1963 r	*1964*
Sheet, plate, and foil:		
Non-heat-treatable	41. 2	41. 1
Heat-treatable	5. 7	5. 9
Foil	7. 6	7. 4
Rolled and continuous cast and bar; wire:		
Rod, bar, etc	2. 9	3. 0
Bare wire, conductor and nonconductor	1. 3	1. 3
Bare cable (including steel-reinforced)	6. 4	6. 4
Wire and cable, insulated or covered	2. 1	2. 1
Extruded rod, bar, pipe, tube, and shapes:		
Alloys other than 2,000 and 7,000 series [1]	25. 4	25. 8
Alloys in 2,000 and 7,000 series	1. 7	1. 2
Tubing:		
Drawn	1. 5	1. 4
Welded, non-heat-treatable [2]	1. 2	1. 6
Powder, flake, and paste:		
Atomized	. 5	. 5
Flaked	. 1	. 1
Paste	. 4	. 4
Forgings (including impact extrusions)	2. 0	1. 8
Total	100. 0	100. 0

r Revised, see table 8.
[1] Includes a small amount of rolled structural shapes.
[2] Includes a small amount of heat-treatable welded tube.

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[3] Dow Chemical Co. MS–80—A Safe Blasting Agent. Eng. News-Record, v. 172, No. 23, June 4, 1964, pp. 39–40.

TABLE 8.—Net shipments[1] of aluminum wrought and cast products by producers

(Short tons)

	1963	1964
Wrought products:		
Sheet, plate, and foil	r 1,158,775	1,315,320
Rolled and continuous cast rod and bar; wire	r 270,378	311,138
Extruded rod, bar, pipe, shapes drawn and welded tubing and rolled structural shapes	r 635,046	723,690
Powder, flake, paste	22,405	23,138
Forgings	r 41,988	44,199
Total	r 2,128,592	2,417,485
Castings r [2]:		
Sand	101,444	115,412
Permanent mold	166,344	162,150
Die	332,652	343,640
Other	3,152	5,630
Total	603,592	626,832
Grand total	2,732,184	3,044,317

r Revised.

[1] Net shipments are total shipments less shipments to other metal mills for furthur fabrication.

[2] Data not comparable to previous years.

Source: Bureau of the Census.

STOCKS

Inventories of aluminum ingot at primary reduction plants declined from 99,100 tons on January 1 to 96,900 tons on December 31. Based on the December production rate, closing 1964 industry stocks were equal to about 2 weeks of output. In addition to the primary aluminum stocks reported, reduction plants also had inventories of ingot and aluminum in process.

Inventories of secondary aluminum alloy ingot decreased 11 percent to 29,000 short tons, equivalent to a 22-day supply based on shipments for the entire year. Consumer's yearend inventories of aluminum scrap decreased slightly to 41,437 tons, equivalent to about a 3-week supply based on the total quantity melted or consumed during the year.

PRICES

The published domestic price for unalloyed primary aluminum was unchanged through March 4 at 23 cents per pound. The price was increased to 23.5 cents per pound on March 5 and was unchanged until the middle of June when it was again raised 0.5 cent per pound to 24 cents per pound. On November 19, a leading domestic producer raised the price to 24.5 cents per pound, and by the end of the year other domestic producers had announced similar increases. The price quoted for superpure aluminum (99.99 percent) at yearend was 44.5 cents per pound, compared with the range of 42.5 to 43 cents per pound quoted at the beginning of the year.

The average of prices quoted by the American Metal Market for clippings, old sheet, castings, and borings and turnings of scrap aluminum increased 0.5 cent per pound during the year. All grades of smelters' alloys increased 1 cent per pound, and steel deoxidizing grades increased 1 cent per pound.

Prices quoted at the end of 1964 for various grades of aluminum scrap clippings ranged from 12.5 to 13 cents per pound for 2075 (75S) to 16 to 16.5 cents per pound for 1100 (2S). Mixed aluminum clippings were quoted at 14.5 to 15.0 cents per pound. Old aluminum sheets and castings were quoted at 12.5 to 13.0 cents per pound, and aluminum borings and turnings were quoted at 13 to 13.5 cents per pound.

Effective at the end of the year quoted delivery prices for 10-ton lots of various grades of smelters' alloy ranged from 22 to 22.5 cents per pound for 380 (AXS–679) alloy containing 3 percent zinc to 30.25 to 30.75 cents per pound for 218 alloy grades. Steel-deoxidizing grades ranged from 20.5 cents per pound for 85 percent aluminum (No. 4 grade) to 24.25 cents per pound for 95 percent aluminum (No. 1 grade).

FOREIGN TRADE

The total quantity of crude and semicrude aluminum imported was 3 percent lower than that of 1963. However, the total value of imports under this class increased, owing to the higher ingot price and increased imports of products with higher unit value, such as plates, sheets, circles, and disks. Imports of crude aluminum metal and alloys from Canada, the principal source, declined, but imports from Norway and Japan increased.

TABLE 9.—U.S. imports for consumption of aluminum, by classes

Class	1963		1964	
	Short tons	Value (thousands)	Short tons	Value (thousands)
Crude and semicrude:				
Metals and alloys, crude	[r] 415,600	[r] $163,414	394,563	$163,419
Circles and disks	5,656	3,687	7,049	4,423
Plates, sheets, etc., n.e.s	[r] 32,257	[r] 19,172	39,389	23,183
Rods and bars	3,555	2,501	4,104	2,760
Scrap	9,306	2,307	8,152	2,038
Total	[r] 466,374	[r] 191,081	453,257	195,823
Manufactures:				
Foil	4,817	5,569	5,292	5,893
Folding rules	(1)	356	(1)	1
Leaf (5.5 by 5.5 inches)	(2)	16	(2)	18
Flakes and powders	158	167	206	206
Table, kitchen, hospital utensils, etc	2,788	[r] 4,179	2,323	3,757
Other manufactures	(3)	6,994	(3)	3,679
Total	(3)	[r] 17,281	(3)	13,554
Grand total	(3)	[r] 208,362	(3)	209,377

[r] Revised.

[1] 1963, 1,605 rules; 1964, value only reported; equivalent weight not recorded.

[2] 1963, 2,770,839 leaves and 11,457,002 square inches of leaf; 1964, 1,578,300 leaves, and 56,882,353 square inches of leaf.

[3] Quantity not recorded.

Source: Bureau of the Census.

TABLE 10.—U.S. imports for consumption of aluminum, by classes and countries

(Short tons)

Country	1963			1964		
	Metal, and alloys, crude	Plates, sheets, bars, etc.[1]	Scrap	Metal, and alloys, crude	Plates, sheets, bars, etc.[1]	Scrap
North America:						
Canada	[r]272,879	[r]2,562	8,489	259,656	3,347	7,849
Other		5	39	390	(2)	93
Total	[r]272,879	[r]2,567	8,528	260,046	3,347	7,942
South America: Argentina		234			16	
Europe:						
Austria	1	1,026		331	1,260	
Belgium-Luxembourg	493	[r]14,612	29	5	19,371	
France	34,677	[r]5,199		14,884	5,269	
Germany, West	[r]432	[r]2,540		189	3,023	
Italy	[r]2	3,622		11	7,150	
Norway	87,087	4		93,906		
Spain	2,058	1,417	9		1,567	
Sweden	701	591	257	460	458	169
Switzerland	1,251	[r]305		2,007	296	
United Kingdom	375	[r]2,597	175	24	521	8
Yugoslavia	[r]1	[r]1,479		110	2,353	
Other	11	111	157	3	117	33
Total	[r]127,089	[r]33,503	627	111,930	41,385	210
Asia:						
Japan	[r]11,596	[r]5,112		15,038	5,544	
Taiwan	[r]440	48		385	227	
Other	175		90	169	22	
Total	[r]12,211	[r]5,160	90	15,592	5,793	
Africa	2,849		61	3,994		
Oceania	572	4		3,001	1	
Grand total	[r]415,600	[r]41,468	9,306	394,563	50,542	8,152
Value, thousands	[r]$163,414	[r]$25,360	$2,307	$163,419	$30,366	$2,038

[r] Revised.

[1] Includes circles and disks, bars and rods, and plates, sheets, etc.

[2] Less than ½ unit.

Source: Bureau of the Census.

TABLE 11.—U.S. exports of aluminum, by classes

Class	1963		1964	
	Short tons	Value (thousands)	Short tons	Value (thousands)
Crude and semicrude:				
Ingots, slabs, and crude	165,340	[r]$70,626	208,622	$92,227
Scrap	71,040	21,369	68,615	21,476
Plates, sheets, bars, etc	53,363	39,276	69,761	50,982
Castings and forgings	1,431	4,017	1,832	4,671
Semifabricated forms, n.e.c	495	55	572	619
Total	291,669	[r]135,343	349,402	169,975
Manufactures:				
Foil and leaf	1,832	2,493	1,666	2,671
Powders and pastes (aluminum and aluminum bronze) (aluminum content)	490	639	554	708
Cooking, kitchen, and hospital utensils	802	2,228	1,179	3,095
Sash sections, frames (door and window)	1,220	2,037	1,775	2,917
Venetian blinds and parts	761	994	729	886
Wire and cable	12,225	6,840	8,632	5,282
Total	17,330	15,231	14,535	15,559
Grand total	308,999	[r]150,574	363,937	185,534

[r] Revised.

Source: Bureau of the Census.

Exports of all classes of crude and semicrude aluminum products, except scrap, increased markedly during 1964. Total exports of the crude and semicrude products increased 20 percent over those of 1963.

The United Kingdom was the destination of most of the aluminum ingots slabs and crude, accounting for 20 percent of the total. West Germany, France, Argentina, Netherlands, and Belgium-Luxembourg accounted for most of the remainder. West Germany, Japan, and Italy were the principal destinations for aluminum scrap.

TABLE 12.—U.S. exports of aluminum, by classes and countries

Destination	1963			1964		
	Ingots, slabs, and crude	Plates, sheets, bars, etc.[1]	Scrap	Ingots, slabs, and crude	Plates, sheets, bars, etc.[1]	Scrap
North America:						
Canada	1,478	25,140	1,621	2,183	37,122	1,849
Mexico	4,498	1,856	24	289	3,110	35
Other	513	1,829	143	867	2,123	84
Total	6,489	28,825	1,788	3,339	42,355	1,968
South America:						
Argentina	7,571	41	----------	13,976	81	----------
Brazil	4,884	112	----------	2,387	69	4
Colombia	4,934	353	10	3,733	175	5
Venezuela	800	1,172	10	2,028	849	16
Other	1,203	735	17	2,362	1,490	22
Total	19,392	2,413	37	24,486	2,664	47
Europe:						
Belgium-Luxembourg	6,367	354	164	10,895	319	75
France	6,670	331	45	22,209	376	80
Germany, West	18,971	1,057	26,552	40,827	1,263	31,937
Greece	3,342	55	----------	3,431	11	----------
Italy	13,217	935	21,771	8,399	2,927	9,326
Netherlands	4,047	2,792	93	12,047	3,003	960
Sweden	2,314	733	----------	1,373	726	4
Switzerland	1,917	162	217	1,255	11	242
United Kingdom	52,265	4,288	4,453	41,307	2,311	7,548
Other	3,058	998	1,049	14,801	1,050	359
Total	112,168	11,705	54,344	156,544	11,997	50,531
Asia:						
India	4,128	8,240	5	1,888	6,671	----------
Israel	1,274	265	----------	2,265	496	3
Japan	3,124	865	14,390	4,100	884	15,333
Korea, South	3,376	12	----------	160	11	----------
Philippines	4,311	52	----------	4,112	56	----------
Other	3,316	761	204	8,183	3,113	352
Total	19,529	10,195	14,599	20,708	11,231	15,688
Africa	2,771	1,458	1	925	3,219	11
Oceania	4,991	693	271	2,620	699	370
Grand total:						
Short tons	165,340	55,289	71,040	208,622	72,165	68,615
Value, thousands	[r] $70,626	$43,348	$21,369	$92,227	$56,272	$21,764

[r] Revised.

[1] Includes plates, sheets, bars, extrusions, castings, forgings, and unclassified semifabricated forms.

Source: Bureau of the Census.

WORLD REVIEW

Production of primary aluminum was 11 percent higher than that of 1963. Output in North America increased by 374,000 tons or 12 percent, and production in Australia and other countries in Asia and

Africa rose about 18 percent, chiefly because of marked increases in output for Australia and Japan. Production in Western Europe increased by 133,000 tons, or 11 percent, but consumption was 200,000 tons, or 14 percent higher. Estimated production of aluminum in communist countries was only 1 percent greater than that of 1963.

TABLE 13.—World production of aluminum by countries[1]

(Short tons)

Country	1955-59 (average)	1960	1961	1962	1963	1964 [p]
North America:						
Canada	603,462	762,012	663,173	690,297	719,390	842,640
Mexico	---	---	---	---	6,100	[e] 16,500
United States	1,682,411	2,014,498	1,903,711	2,117,929	2,312,528	2,552,747
Total	2,285,873	2,776,510	2,566,884	2,808,226	3,038,018	3,411,887
South America: Brazil	10,320	20,034	22,078	22,202	19,412	[e] 28,000
Europe:						
Austria	65,135	74,924	74,578	81,668	84,287	85,646
Czechoslovakia	25,280	44,100	55,100	[e] 65,000	[e] 65,000	[e] 65,000
France	172,085	262,890	308,047	325,288	328,891	347,669
Germany:						
East [e]	36,300	44,000	50,000	50,000	50,000	50,000
West	160,098	186,221	190,212	196,017	230,142	242,418
Hungary	40,132	54,602	56,286	58,127	61,176	62,693
Italy	72,896	92,206	91,881	89,549	100,784	127,337
Norway	116,107	181,662	189,109	226,966	241,583	278,444
Poland (includes secondary)	23,768	28,640	52,488	53,007	51,365	52,639
Spain	15,439	31,680	41,500	45,953	50,142	68,092
Sweden (includes alloys)	14,391	17,619	17,463	17,580	20,172	33,510
Switzerland	34,665	43,795	46,530	54,640	67,440	70,805
U.S.S.R. [e]	560,000	705,000	980,000	990,000	1,060,000	1,100,000
United Kingdom	29,637	32,390	36,169	38,113	34,243	35,516
Yugoslavia	18,788	27,635	30,211	30,843	39,567	38,320
Total [e]	1,385,000	1,825,000	2,220,000	2,325,000	2,485,000	2,660,000
Asia:						
China [e]	30,300	88,200	110,000	110,000	110,000	110,000
India	10,477	20,123	20,263	39,025	60,856	60,830
Japan [2]	82,939	146,853	169,424	188,191	246,854	292,950
Taiwan	8,836	9,106	9,938	12,135	13,148	19,565
Total [e]	132,600	264,300	309,600	349,400	430,900	483,300
Africa: Cameroon, Republic of	[3] 30,021	48,436	52,446	57,596	58,327	[e] 55,800
Oceania: Australia	9,689	13,054	14,789	18,090	46,214	88,507
World total (estimate)[1]	3,855,000	4,950,000	5,185,000	5,580,000	6,080,000	6,730,000

[e] Estimate. [p] Preliminary.

[1] This table incorporates some revisions. Data do not add exactly to totals shown because of rounding where estimated figures are included in the detail.

[2] Includes superpurity: 1955–59 (average), 594 tons; 1960, 2,187; 1961, 1,307; 1962, 1,969; 1963, 2,060; and 1964, 2,092 tons.

[3] Average annual production 1957–59.

NORTH AMERICA

Canada.—Output of 843,000 short tons of primary aluminum was a new record, 17 percent above that of 1963. Aluminum Company of Canada, Ltd. (Alcan), accounted for 740,000 tons of the total and the Canadian British Aluminium Company, Ltd. (C.B.A.), the remainder. About 80 percent of the total output was exported, chiefly to the United States and the United Kingdom.

According to the Canadian British Aluminium Co., Ltd., its aluminum smelter at Baie Comeau, Quebec, had a capacity of 100,000 tons of aluminum ingot per year, which could be increased progressively to 115,000 tons per year with minor modifications to existing equipment and improved operating techniques.

The startup during the year of the new aluminum canmaking facility of Maritime Cans, Ltd., at Dartmouth, Nova Scotia, and the 25,000-ton-per-year aluminum rod plant of Reynolds Extrusion Co., Ltd., at La Malbaie, Quebec, highlighted the substantial gains which have been achieved in domestic consumption in recent years. The operating companies at each of these new plants were subsidiaries of Reynolds Metals Co. of the United States.

In keeping with the trend of recent years toward greater integration of production facilities on an international level, Alcan moved to acquire control of the Alroll, Inc., plant at Oswego, N.Y., which was capable of producing 100,000 tons of aluminum reroll sheet stock per year. The aluminum sheet-rolling plants in the United States of Cerro Aluminum Co. and Bridgeport Brass Co., also were to be acquired. Other foreign acquisitions or expansion planned by Alcan included the purchase of a controlling interest in Fisher Foils Co., a producer of tin and aluminum foils in the United Kingdom.

A report indicated that as of August 1964 the world capacity of Alcan and its subsidiaries was 1 million tons of aluminum ingot and about 650,000 tons of fabricated and semifabricated aluminum products. In 1964 sales of aluminum ingot and ingot products of the group totaled 508,000 tons. Fabricated and semifabricated aluminum products sales totaled 355,000 tons.

Netherlands Antilles.—Plans for the construction of an aluminum smelter in Curacao reportedly were under consideration by Kaiser Aluminum & Chemical Corp., Shell Curacao N.V., and Curacao interests.

SOUTH AMERICA

Brazil.—Estimated production of primary aluminum increased to a record high of 28,000 tons. However, aluminum consumption was believed to have decreased. Although annual domestic output has increased steadily since 1951, about half of the country's requirement for primary aluminum ingot still is imported. In recent years several attempts to establish new aluminum production facilities have been unsuccessful.

During 1964 tentative plans for a $50 million integrated bauxite mining and aluminum smelting project, near Pocos de Caldos, were under consideration by the Aluminum Company of America (Alcoa), the State Government of Minas Gerais, and Brazilian interests.

Venezuela.—The Corporacion Venezolana de Guayana announced that Reynolds International, Inc., a subsidiary of Reynolds Metals Co., would begin construction of the proposed 10,000-ton-per-year aluminum smelter in the Guayana district late in the year. The new plant was expected to use imported raw materials but would obtain electric power from the Caroni hydroelectric plant on a tributary of the Orinoco River.

EUROPE

Of the five principal aluminum-consuming countries in Western Europe, Belgium and Luxembourg had the largest percentage increase in consumption of primary aluminum from 1961 to 1964, gaining 65 percent. The United Kingdom, with a 26-percent gain during the period, achieved the highest tonnage increase, 82,000 tons. The overall gain in primary aluminum consumption from 1961 to 1964 was about 30 percent, representing an average annual growth rate of 9 percent per year.

TABLE 14.—Europe: Consumption of primary aluminum

(Thousand short tons)

	1961	1962	1963	1964 [p]
United Kingdom	313.2	315.8	351.1	395.6
Germany, west	320.2	323.3	334.4	390.2
France	227.2	259.7	267.3	274.8
Italy	115.7	126.8	141.1	154.3
Belgium and Luxembourg	73.7	74.4	98.0	121.3
Switzerland	51.4	57.4	(1)	56.2
Sweden	37.4	43.8	55.9	56.4
Austria	41.4	37.6	46.0	50.7
Spain	22.0	24.3	24.3	50.7
Norway	25.5	25.9	23.7	40.8
Other [2]	38.6	43.8	46 8	53.6
Total	1,266.3	1,332.8	1,440.0	1,644.6

[p] Preliminary.
[1] Data not available. Estimates included in the total.
[2] Netherlands, Greece, Denmark, Portugal, Ireland, and Turkey.

Source: Organization for Economic Cooperation and Development.

France.—Annual capacity of the Nogueres aluminum smelter of Péchiney, Compagnie de Produits Chimique et Electrométallurgiques, was increased to 113,500 short tons per year.

Germany, East.—A report indicated that construction of the first stage of the new aluminum smelter at Lauta, with an annual capacity of 12,000 tons, was nearing completion. The plant consisted of 64 furnaces.

Germany, West.—Vereinigte Aluminium Werke, A. G. (VAW), planned to expand its annual aluminum capacity to a total of 220,000 tons compared with the 192,000 tons existing at the end of 1964. VAW expected the expansion to be achieved within 2 or 3 years by rationalization and relatively minor modifications at each of its four plants.[4]

Kaiser Aluminum-Werke G.m.b.H., a subsidiary of Kaiser Aluminum & Chemical Corp., continued construction of its Koblenz aluminum fabricating plant and started production of rolled products on a 148-inch-wide hot mill. Kaiser also formed a new company, Kaiser Aluminum Kabel Werk G.m.b.H., to build and operate a $3.5 million aluminum rod and cable plant in Berlin. Reynolds International, Inc., a wholly owned subsidiary of Reynolds Metals Co., purchased a major aluminum extrusion and sheet plant at Westphalia. The former operating company, Westfalische Leichmetallwerke G.m.b.H., was renamed Reynolds Aluminumwerke G.m.b.H.

It was reported that Kaiser was discussing the establishment of a 50,000-ton-per-year aluminum smelter to be built at Emden on the North Sea.

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[4] Metal Industry (London). Aluminum Capacity to be Increased for W. Germany Producer. V. 105, No. 7, Aug. 13, 1964, p. 198.

Greece.—Construction of the new 67,500-ton-year-year aluminum smelter of Aluminium de Grèce, S.A. was continued, but disagreement on the cost of power to the plant threatened to delay the project. The cost of the power from the Castraki hydroelectric station on the Acheloos River, which was scheduled to be completed before 1966, was expected to be about 4.4 mills per kw-hr instead of the 3.2 mills per kw-hr called for in initial discussions.

Viohalco S.A. applied to the Government for a license to construct a 15,000-ton-per-year aluminum smelter to supply its own needs for primary aluminum.

Italy.—Societe Aluminio Veneto per Azioni (SAVA) began producing primary aluminum from a new 22,000-ton-per-year smelter at Fusina.[5]

A new company, as yet unnamed, was formed by Societa Mineria Carbonifera Sarda (Carbosarda), Societa Atlantic of Brussels, and Harvey Aluminum, Inc., to study the feasibility of using Sardinian bauxite in a proposed new aluminum smelter to be built in Sardinia. An agreement provided for participation by Montecatini, Soc. Generale per l'Industria Mineraria e Chimica.

Norway.—A/S Aardal og Sunndal Verk planned to build a new aluminum smelter at Sunndalsora with a capacity of about 50,000 tons per year, bringing the total capacity of the company to 250,000 tons per year by 1967. Production of primary aluminum from two other new plants under construction at Karmoy (Alnor A/S) and at Husnes (Sor Norge Aluminium A/S), each with an annual capacity of 66,000 tons also was expected by 1967. Other planned expansions included a 30,000- to 40,000-ton-per-year increase in the capacity of the Det Norske Nitrid A/S Tyssedal smelter and a new 33,000-ton-per-year smelter for Mosjoen Aluminum A/S at Lista. New plants under construction or in various stages of planning were expected to raise primary aluminum capacity to about 550,000 tons per year by 1970.

Poland.—The first stage of the 66,000-ton-per-year aluminum smelter at Konin was expected to be completed in 1966 and capacity expanded to 100,000 tons per year by 1970.

Spain.—According to the Four Year Development Plan, which started January 1, 1964, aluminum production was to be increased from 50,000 tons per year in 1963 to 77,000 tons in 1967. Annual capacity at the end of 1964 and planned by 1967 is estimated as follows:

	Capacity, short tons	
	Dec. 1964	*Dec. 1967*
Empresa Nacional del Aluminio, S.A.:		
Valladolid	14,000	26,000
Aviles	20,000	33,000
Aluminio Espanol, S.A.: Huesca	8,200	8,200
Aluminium de Galicia: La Coruna	13,000	13,000
Total	55,200	80,200

U.S.S.R.—Production of primary aluminum reportedly began at the new smelter at Krasnoyarsk. Capacity of the plant at the end of the year was probably about 30,000 tons per year.

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[5] Metal Bulletin (London). Aluminum. No. 4947 Nov. 13, 1964, p. 30.

Yugoslavia.—The Yugoslav Investment Bank was investigating the possibility of financing the development of an integrated aluminum industry at Mostar, Hercegovina, in cooperation with various private and government organizations in France, Italy, Japan, Norway, Hungary and the United States.

ASIA

India.—Owing to the Government's interest in reducing the dependence on imported base metals for use in the electrical industries by substituting domestically produced aluminum, total output of primary aluminum by 1970 was expected to approach 150,000 tons compared with the 60,000 tons produced in 1964.

The new 11,000-ton-per-year aluminum smelter at Mettur, Salem, being built by Madras Aluminium Co., Ltd., in collaboration with Montecatini, was expected to start production in 1965. The Indian Aluminium Co., Ltd., was expanding capacity of its Alwaye smelter from 8,000 tons to 14,000 tons per year and planned a new 33,000-ton-per-year plant in Mysore. Hindustan Aluminium Corp., Ltd., obtained partial financing for work on increasing capacity of its aluminum smelter at Renukoot, Uttar Predesh, from 22,000 tons per year to about 55,000 tons per year by 1967.

Indonesia.—Construction of a 27,000-ton-per-year aluminum smelter at Belawan, North Sumatra, was planned to start in 1965. However, Soviet engineers reportedly had just completed design of the proposed 280,000-kw hydroelectric power station on the Asahan River during 1964 (which presumably will supply electricity to the smelter), and production of aluminum at the proposed plant does not appear likely before 1968.

Japan.—Output of primary aluminum increased 19 percent to 293,000 tons as producers brought in new capacity during the year. Sumitomo Chemical Co., Ltd., increased capacity of its Nagoya smelter by 20,000 tons to 50,000 tons per year, and annual capacity of the Japan Light Metals Co., Ltd., Kambara aluminum smelter was increased by 6,000 tons to 85,000 tons. By 1966 Mitsubishi Chemical Co. was expected to double aluminum capacity of its Naoestsu smelter to 66,000 tons per year, and Showa Denko K.K. planned to increase annual capacity at its three plants by 20,000 tons to 110,000 tons.

Taiwan.—Taiwan Aluminium Corp. expanded capacity of its aluminum smelter at Takao to 25,000 tons per year and planned to increase output of aluminum sheet and fabricated products to about 20,000 tons per year.

AFRICA

Cameroon.—Production of 56,000 tons of primary aluminum by the Compagnie Camerounaise de l'Aluminum Péchiney-Ugine (ALUCAM) at Edea was below the record output of 1963, owing to unfavorable water conditions at the hydroelectric plant on the Sanaga River at Edea. By 1966 a new dam was expected to be built to regulate the flow of the Sanaga, permitting production to be increased to 64,000 tons per year.

Ghana.—Construction was begun on the new aluminum smelter of Volta Aluminum Co., Ltd. (owned 90 percent by Kaiser and 10 percent by Reynolds). Besides the reduction plant, the Volta project will include construction of a dock at Tema and facilities for vacuum unloading of alumina, coke, and pitch; aluminum loadout; handling and storage of raw materials; and a haulage road. Major facilities at the smelter, which will be 2 miles from the dock, will include three potlines with a total of 300 reduction cells, a rodding room, carbon baking furnaces, and a green carbon plant. Power for the 140,000-ampere prebake reduction cells will be supplied by the new hydroelectric station at Akosombo, about 50 miles to the northwest on the Volta River. According to the schedule of the quantity of electricity that Valco had contracted to purchase, initial output from the smelter of about 30,000 tons is expected in 1967. Output is expected to increase to about 100,000 tons per year in 1969 and reach 150,000 tons in 1972.

South Africa, Republic of.—The Industrial Development Corp. and various foreign interests were discussing the possibility of establishing an aluminum smelter. Consumption of imported aluminum, which in 1963 and 1964 was estimated to be about 15,000 tons and 29,000 tons, respectively, was projected to reach 50,000 tons per year by 1969.

United Arab Republic (Egypt).—The Government reportedly signed an agreement with the Director General of the Polish Centrazao organization for the construction of a 44,000-ton-per-year aluminum smelter and a 30,000-ton prebaked electrode plant at Aswan. Cost of the project was to be $19 million.

OCEANIA

Australia.—Alcoa of Australia, Pty., Ltd., was considering construction of a 150,000-kw thermal power generating plant at Anglesea, about 20 miles from its 44,000-ton-per-year aluminum smelter at Geelong. Design of the plant, which will be based on brown coal, reportedly was underway. Construction of the facility would permit capacity of the Geelong smelter to be doubled.

TECHNOLOGY

At the International Aluminum Symposium held at New York in February, R. E. Oehler of Swiss Aluminum Ltd., discussed the operating efficiency and possible ways for making further improvements in the 100,000-ampere cell pots, used by his company. Average energy consumption was 6.35 kw-hr per pound of aluminum produced with a current efficiency of 89 percent. Experimental use of an automatic system for controlling the anode effect, indicated that the total pot voltage could be reduced by 0.18 volts corresponding to a 0.26-kw-hr-per-pound drop in energy consumption. Unlike many firms, Allusuisse fastens prebaked anode blocks to the stubs by pressing carbon paste into the cavities. The report claimed this technique required less manpower and in addition, good electrical contact was obtained faster than when the anodes were fastened to stubs with cast iron.

It was estimated that the additional investments necessary to produce, transport, and store the floury type of alumina which they used, compared with the sandy type used in the United States, are offset by a 0.25 to 0.5 kw-hr per pound reduction in energy consumption. Floury alumina reportedly contained less water, had better heat-insulating properties, and dissolved in the bath faster than the sandy type.

Losses in current efficiency in operating alumina reduction cells have been attributed to reactions between aluminum dissolved or suspended in the electrolyte and the anode gasses; that is, oxides of carbon. However, a mechanism of this so-called "back reaction" has not been generally accepted. An investigation of the reaction velocities at various oxygen potentials, electrolyte depths, thermodynamic activities of the aluminum, and mass transfer conditions indicated that the transfer of aluminum from the electrolyte-metal interface to the electrolyte-gas interface, determined the rate of the reaction leading to aluminum losses and low current efficiency.[6]

In another study oxides of carbon were bubbled through the electrolyte, which would tend to minimize the effect of the rate-determining transfer of aluminum through the melt. In this study, analysis of the effluent gases showed that carbon dioxide is reduced not only to carbon monoxide as commonly assumed but a part of the latter is further reduced to carbon. The extent of both reactions was strongly dependent on the ratio of sodium and aluminum fluorides and decreased with increasing aluminum fluoride content, suggesting that part of the aluminum in the electrolyte was present in a state which does not react with oxides of carbon.[7]

Changes in the composition of gases evolving from aluminum reduction cells were studied as a possible means of automatically controlling the operation of the cell.[8] A report indicated that previous investigations were based on the assumption that the only source of carbon monoxide in the effluent gas was the reaction between aluminum and carbon dioxide; however, recent studies showed that a considerable portion of the carbon monoxide resulted from reactions between carbon and carbon dioxide and other reactions not related to the oxidation of aluminum with carbon dioxide.[9]

Calcination of petroleum coke for use as anode material in electrolytic production of aluminum was described. A 16-man production crew operated the plant three shifts a day, year round, shutting down only for repairs. Each day about 1,000 tons of green delayed coke (from delayed cokers), containing 12 to 15 percent moisture, is sized and crushed and fed into two 180-foot by 10-foot rotary kilns fired with natural gas. Kiln temperature is about 1200° F, but ultimate coke calcination takes place at 2,500° F midway in the kiln.

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[6] Gierstad, Sigbjorn, and B. J. Welch. The Oxidation of Aluminum by Carbon Dioxide in the Presence of Cryolitic Electrolyte. J. Electrochem. Soc., v. 3, No. 8, August 1964, pp. 976–980.

[7] Thonstad, Jomar. On the Anode Gas Reactions in Aluminum Electrolysis. 1. The Reactivity of Dissolved Aluminum in NaF-AlF_3-Al_2O_3 Melts and On the Anode Gas Reactions in Aluminum Electrolysis, II. J. Electrochem. Soc., v. 3, No. 8, August 1964, pp. 955–965.

[8] Saakyan, P. S. A Determination of the Indices for the Process of Electrolytic Production of Aluminum by the Composition of Anode Gases. Soviet J. Non-Ferrous Metals (English transl. Tsevtnye Metally), v. 4, No. 3, 1963, pp. 33–37.

[9] Kostyokov, A. A. Relationship of the Current Efficiency in Electrolytic Production of Aluminum to the Composition of Anodic Gases. Soviet J. Non-Ferrous Metals (English transl, Tsetnye Metally), v. 4, No. 3, 1963, pp. 38–44.

One and one half hours are normally required for a particle of coke to travel the length of the kiln. The coke (about 75 percent of the green coke feed) leaves the kiln at about 2,300° to 2,400° F and is water quenched in two rotary coolers 70 feet long by 8 feet in diameter. The coke is kept dry after calcining by use of enclosed conveyors and covered storage tanks.[10]

A review of carbothermic smelting processes for producing alumina or aluminum metal emphasized the importance of reactions involving oxycarbides and monovalent compounds of aluminum which prevent adequate recovery of the aluminum in such processes.[11] An analysis of the thermodynamics of the aluminum-carbon-oxygen system indicated that available information on oxychloride reactions may be based on kinetic conditions rather than stable equilibria as reported in the literature.[12]

Several patents pertaining to the production of aluminum by the reduction of alumina with carbon were issued. In one,[13] a first stage product was prepared by reacting a briquetted mixture of carbon, alumina, and aluminum carbide at about 2,000° C. An aluminum trihalide, such as aluminum trichloride, was reacted with the product which contains aluminum carbide. It was claimed that the second stage, which was conducted at a relatively low temperature of 1,300° C, avoids the risk of evaporation losses caused by the direct formation of aluminum or aluminum suboxides.

A process was patented for the preparation of briquets of carbon and alumina made by mixing stoichiometric proportions of alumina and carbon having a controlled grain size and adding 3 to 30 percent of an aqueous alkaline solution to form a dry paste, which is granulated and dried at about 200° C to form porous briquets of high strength.[14]

The standard heat of formation of aluminum carbide at 298° K, which is a factor in carbothermic reduction processes was determined by the Bureau of Mines as 53.4 kcal per mole.[15] A National Bureau of Standards report, which corrected for the formation of delta alumina when aluminum carbide is oxidized, gave 49.7 kcal per mole for the standard heat of formation of aluminum carbide at 298° K.[16]

A patent issued to Aluminium Laboratories, Ltd., described a method of protecting graphite heating electrodes from the corrosive effects of aluminum monochloride formed in the reaction between aluminum trichloride and aluminum metal. The method involved recessing the electrodes in the sides of the the reaction vessel and maintaining a film of gaseous aluminum trichloride over the exposed graphite electrode.[17]

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[10] Taeler, David H. Calcined Coke for Aluminum Manufacture. Minerals Processing, v. 5, No. 5, May 1964, pp. 24–26.

[11] Stroup, P. T. Carbothermic Smelting of Aluminum. Trans. Met. Soc., AIME, v. 230, No. 3, April 1964, pp. 356–372.

[12] Morfopoulos, Vassilis C. P. Analysis of the Thermodynamics of the Al-C-O System in the Temperature Range 1,000 to 1800° K. Canadian Met. Quart., v. 3, No. 1, January–March 1964, pp. 95–115.

[13] A Method of Producing Aluminum. British Pat. 952,297, Mar. 11, 1964.

[14] Ruelle, Louis, and Jacques Clair (Grenoble, France). Process for the Preparation of Aluminum Oxide and Carbon Based Briquettes. U.S. Pat. 3,135,696. June 2, 1964.

[15] Mah, Alla D. Heat of Formation of Aluminum Carbide. BuMines Rept. of Inv. 6415, 1964, 4 pp.

[16] King, R. C., and G. T. Armstrong. Heat of Combustion and Heat of Formation of Aluminum Carbide. NBS J. Research, Physics and Chemistry—Sec. A, V, 68A, No. 6, November–December 1964, pp. 661–668.

Heat exchangers used in extracting helium from natural gas were fabricated of aluminum and weighed as much as 50 tons each.[18] The aluminum tubing was wound on rotating mandrels.

Construction of a 50-foot aluminum submarine, developed by Reynolds Metals Co. to explore the ocean floor down to depths of nearly 3 miles, resulted in significant advances in handling and fabricating large sections of aluminum.[19] The hull of the submarine was made by bolting together 11 close-fitting forged-aluminum cylinders 8 feet in diameter, 40 inches long and 6.5 inches thick. One of the 12 ingots used in forging the cylinders and end pieces weighed 17 tons and was believed to be the largest ever cast in aluminum.

Aluminum sheet was formed by passing it through two rollers, one of which was made of urethane rubber.[20] Parts formed on these rolls fitted design specifications, showed no evidence of spread, and were produced at a much higher rate than when conventional dies were used. The rolls also could be used to straighten coil stock by reverse feeding.

A report indicated that wider use of continuous casting in the aluminum industry was expected because of increasing competition and rising costs.[21] Some of the available methods that were discussed are summarized as follows:

Process:	*Manufacturer*	*Product*
Hunter	Hunter Engineering Co	Aluminum strip 0.186 to 0.312 inch thick, unlimited widths.
Hazlett	Hazlett Strip Casting Corp	Strip 0.375 inch thick, and over 63 inch widths.
Properzi	Nichols Wire & Aluminum Co., Ltd.	Redraw rod, narrow strip, extrusion slugs.
Mann	Albert Mann Engineering	20-inch strip and extrusion slugs.
Ugine-Venthon.	Societé, d'Électro-Chimie, d'Électro-Métallurgie et des Aciéries Electriques d'Ugine (Ugine).	Slabs 4 to 8 inches thick, and billet 4 inches and over.

Costs of the machines ranged from $250,000 to $1,000,000 depending on the product made, speed, and other factors.

The quality of molten aluminum alloys was improved by combining filtering and fluxing operations in one step.[22] Inert gas was diffused countercurrently to the flow of the molten metal through a filtering bed.

The surface lubricity of aluminum was improved by impregnating tetrafluorethylene into the oxide coating.[23] Plastics such as vinyls polyolefins, and a chlorinated polyether were coated on aluminum to provide improved corrosion and abrasion resistance.[24]

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[17] Southam, Frederick William (Arvida, Quebec, Canada). Protection of Graphite Surfaces from Attack by Aluminum Monochloride. U.S. Pat. 3,161,500, Dec. 15, 1964.

[18] Irving, R. R. Wound Tubing: Novel Approach To Aluminum Fabrication. Iron Age, v. 193, No. 19, May 7, 1964, pp. 73–75.

[19] Modern Metals. Aluminum Metalworking Advances Developed in Aluminum Sub Project. V. 20, No. 3, April 1964, pp. 60, 62.

[20] Modern Metals. Rubber Rolls Form Precision Parts. V. 20, 9, October 1964, p. 62.

[21] Steel. Continuous Casting of Aluminum May Pick Up. V. 154, No. 13, Mar. 30, 1964, pp. 132, 134.

[22] Brondyke, K. J., and P. D. Hess. Filtering and Fluxing Processes for Aluminum Alloys. Trans. Met. Soc. AIME., v. 230, No. 7, December 1964, pp. 1553–1556.

[23] Industrial Research. Teflon Coated Aluminum. V. 6, No. 11, December 1964, pp. 95, 98–99.

In a new laminate the thermal insulating properties of aluminum were combined with the porosity, flexibility, and other properties of fabric.[25] Aluminum foil is forced into the spaces between individual textile threads, breaking the foil and wrapping it part way around the thread. The foil is visible from one side only, and the opposite side retains its original appearance. One of the new material's more important properties is a high reflectivity of radiant heat—about 90 percent. Potential uses include air-conditioning, protective garments, and tents.

Aluminum coatings applied by evaporating the metal and condensing it on the part to be plated protects steel from corrision at temperatures up to 900° F.[26] Self-supporting forms of aluminum also were made by vapor depositing the metal on a mandrel in a vacuum. A commercial process for vapor coating aluminum on light-gage flat-rolled steel as a substitute for tinplate was announced by United States Steel Corp.[27] In the process aluminum is vaporized in a vacuum by an electron beam, then deposited as a tin layer on a rapidly moving strip of steel.

A laboratory process for coating aluminum on various materials by decomposition of an organometallic compound (tri-isobutyl aluminum) was reported.[28] Coatings of aluminum alloys, intermetallic compounds, and other materials by codeposition techniques utilizing two or more plating compounds were being investigated.

A photosensitive anodized aluminum plate was reportedly developed which, when processed, provides a permanent, weather-resistant image.[29]

Recent advances in aluminum semifabricating, heat treatment, and alloy development were discussed in a report. Availability of wide aluminum sheet (93 to 96.5 inches); continuous heat-treating lines capable of handling 56 inch coil widths; impact, spiral, and patterned extrusions; and new extrusion alloys were among the developments discussed.[30]

A method was patented for recovering matallic aluminum from aluminum dross by partially fusing a mixture of four parts by weight of crushed aluminum dross and about one part by weight of sodium or potassium nitrate. Charcoal is then added and the exothermic reaction between the charcoal and nitrates provides sufficient heat to complete melting of the contained aluminum which is coalesced by agitation.[31]

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[24] Sandford, J. E. Coatings Form "Unbreakable" Bonds. Iron Age, v. 194, No. 8, Aug. 20, 1964, pp. 53–55.

[25] American Metal Market. Archer Spins Foil and Fabric Into Laminate With Broad Prospects. V. 71, No. 180, Sept. 16, 1964, p. 19.

[26] Chemical Engineering. Vapor-Coating puts Aluminum and Other Metals on Flat-rolled Steel. V. 71, No. 26, Dec. 21, 1964, p. 25.

[27] Clough, Philip J., and John V. E. Hansen. Thick Films: Promising Prospect for Vacuum Metallizing. Metal Prog., v. 86, No. 6, December 1964, pp. 78–81.

[28] Crosby, J. J. Pure Aluminum Coatings Are Uniform and Nonporous. Mat. in Design Eng., v. 59, No. 6, June 1964, pp. 108, 109.

[29] Modern Metals. A Photo-Sensitive Anodized Aluminum Plate. V. 20, No. 3, April 1964, p. 20.

[30] Kobrin, C. L. Aluminum's Boiling Pot of Ideas. Iron Age, V. 193, No. 25, June 18, 1964, pp. 93–100.

[31] Heins, Sidney M. (assigned to Chemical Products Corp., Chicago, Ill.). Process for Recovery of Aluminum From Aluminum Dross. U.S. Pat. 3,155,494, Nov. 3, 1964.

An aqueous explosive composition based on ammonium nitrate containing 1 to 8 percent of finely divided flake aluminum metal was patented.[32]

Data obtained in Bureau of Mines studies of dust explosions of various metals including aluminum were reported.[33] The natural oxide coating on atomized aluminum was given as the probable reason that this material does not ignite in the furnace. However, a high voltage spark does ignite it. The flaked aluminum having a stearic acid or other protective coating is readily ignited in the furnace or by a spark. Both the pressure and the rate of pressure rise are higher for the flaked than for the atomized aluminum and the explosibility index (an empirical measure of the hazard) for the flaked aluminum is about twice that for atomized aluminum.

Trends in an index of output per man-hour in the aluminum industry from 1947 to 1962 were discussed in a report by the U.S. Department of Labor.[34] Output per man-hour of all employees in the primary aluminum industry increased 108 percent or at an average rate of 5.4 percent per year during the period under study. The average annual gain in output per man-hour of production workers was 5.9 percent.

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[32] Breza, Cyril J., and Charles H. Noren (assignors to E. I. du Pont de Nemours and Co., Inc., Wilmington, Del.) Aqueous Explosive Composition Containing Flake Aluminum and Ammonium Nitrate. U.S. Pat. 3,153,606, Oct. 20, 1964.

[33] Jacobson, Murry, Austin R. Cooper, and John Nagy. Explosibility of Metal Powders. BuMines Rept. of Inv. 6515, 1964, 25 pp.

[34] U.S. Department of Labor. Indexes of Output Per Man-Hour. Primary Aluminum Industry 1947–62. Bureau of Labor Statistics, 15 pp.

Antimony

By Donald E. Moulds[1]

◆

ANTIMONY was in short supply during the first 9 months of 1964, resulting in a major increase in price and some manufacturing slowdown, especially in the use of oxide. An increase in imports during the last half of the year and sale of 1,160 tons of antimony from government stocks delivered to industry in November, however, brought about an improved supply-demand balance by the end of the year.

The new supply of antimony, including primary smelter output and general imports of metal and oxide, was approximately equal to the 19,900 tons in 1963. Consumption, as reported to the Bureau of Mines, declined some 700 tons to 15,800 tons and industry stocks at yearend were 200 tons larger than those indicated at the beginning of the year. Secondary production increased to 22,000 tons in company with the record level of secondary lead output in 1964.

Legislation and Government Programs.—Government stocks of antimony totaled 52,796 tons at yearend. Of the total inventory, the strategic stockpile contained 30,092 tons, and the supplemental stockpile contained 22,704 tons. Approximately 850 tons, on order through the agricultural barter program at the end of 1963, was delivered and transferred to the supplemental stockpile and 1,160 tons of antimony was delivered to industry from the stockpile under Public Law 88–615.

DOMESTIC PRODUCTION

MINE PRODUCTION

Output of antimony, predominantly as a byproduct of silver-lead ore refining by the Sunshine Mining Co. in Idaho, was curtailed by a labor shutdown terminating on March 22, 1964. Production of a small tonnage of antimony in concentrates was reported from Nevada and Alaska and, while production was 631 tons, reported shipments amounted to 789 tons of metal content. Earl Pilgrim shipped 40 tons of antimony concentrate from the Stampede mine near Fairbanks, Alaska. Meissner & Son shipped silver-lead-antimony ore from the Goodhope mine near Lovelock, Nev. The White Caps flotation mill started operations in July on ore from mines near Austin, Nev. Significant development was accomplished preliminary to reopening mines in Alaska, Oregon, and Nevada.

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[1] Commodity specialist, Division of Minerals.

SMELTER PRODUCTION

Primary.—Primary smelters produced 13,400 tons of primary antimony products, a 10-percent increase over the 1963 total. Smelter feed was augmented by a 9-percent increase in imports of ore with most of the increase from Bolivia. An additional 400 tons of antimony in ore was delivered from Government stocks to processors in November. Smelter output was derived from the following primary sources: 5 percent from domestic mine production of antimony concentrate, 8 percent from commingled domestic ores and recovered as a byproduct at lead smelters, and 87 percent from foreign antimony ores and base metal ores. Recovery of antimony as a lead-smelter byproduct represented 19 percent of the total primary antimony output.

Antimony metal was produced by National Lead Co. and Sunshine Mining Co.; oxide was produced by American Smelting and Refining Company, Harshaw Chemical Co., McGean Chemical Co., M&T Chemicals, Inc., and National Lead Co. Antimony sulfide, including ground high-grade ore, was produced by Foote Mineral Co., Hummel Chemical Co., and McGean Chemical Co. Byproduct antimonial lead was produced at lead refineries operated by American Smelting and Refining Company, The Bunker Hill Co., St. Joseph Lead Co., and United States Smelting Lead Refinery, Inc.

Secondary.—The recovery of secondary antimony amounted to 22,300 tons, an increase of 7 percent over the 1963 output, and reflects the record activity of the secondary lead smelters. The rise in price of antimony resulted in a significantly higher value for the secondary antimony derived from scrap. Secondary-lead smelters recovered 20,800 tons of antimony, and primary smelters recovered 300 tons from scrap. Manufacturers and foundries produced 1,200 tons. Old scrap contributed 89 percent of the antimony recovered and, of the antimony recovered from old scrap, batteries contributed 69 percent.

TABLE 1.—Salient antimony statistics

(Short tons)

	1955–59 (average)	1960	1961	1962	1963	1964
United States:						
Production:						
Primary:						
Mine	663	635	689	631	645	632
Smelter [1]	10,195	9,954	11,329	11,727	12,117	13,358
Secondary	21,986	20,104	19,466	19,362	20,803	22,339
Imports, general (antimony content)	13,282	14,519	13,942	16,833	17,781	16,698
Exports	121	906	44	45	143	807
Consumption [2]	13,892	13,271	12,697	15,452	16,532	15,839
Price: New York, average cents per pound	33.05	31.30	33.89	34.75	34.75	42.22
World: Production	56,300	58,800	57,200	59,200	61,600	68,000

[1] Includes primary content of antimonial lead produced at primary lead smelters.

[2] Includes primary content of antimonial lead produced at primary lead smelters and antimony content of alloys imported.

TABLE 2.—Antimony mine production and shipments in the United States

(Short tons)

Year	Antimony concentrate		Antimony	
	Quantity	Antimony content, percent	Produced	Shipped
1955–59 (average)	3,945	17.5	663	629
1960	4,256	14.9	635	1,086
1961	4,245	16.2	689	1,646
1962	3,941	16.0	631	732
1963	3,540	18.2	645	503
1964	3,296	19.2	632	789

TABLE 3.—Primary antimony produced in the United States

(Short tons, antimony content)

Year	Class of material produced					Total
	Metal	Oxide	Sulfide	Residues	Byproduct antimonial lead	
1955–59 (average)	3,318	4,513	96	532	1,736	10,195
1960	3,665	5,188	60	385	656	9,954
1961	4,558	4,609	84	355	1,723	11,329
1962	4,407	4,788	53	366	2,113	11,727
1963	4,160	5,983	76	392	1,506	12,117
1964	4,418	6,748	53	447	1,692	13,358

Other sources of old scrap were type metal, 17 percent; babbitt, 8 percent; and cable lead and other antimonial lead, 6 percent. Recovery from mixed drosses and residues, indicated as new scrap, were approximately 100 tons above that reported in 1963. The antimony content of secondary lead materials smelted forms the basic antimony content of the antimonial lead produced with removal or addition of antimony as necessary in the refining stage to meet specifications for the various antimonial-lead alloys. About 3,300 tons of primary antimony was used by secondary smelters and remelters to supplement the secondary supply.

TABLE 4.—Secondary antimony produced in the United States, by kind of scrap and form of recovery

(Short tons, antimony content)

Kind of scrap	1963	1964
New scrap:		
Lead-base	2,156	2,272
Tin-base	96	87
Total	2,252	2,359
Old scrap:		
Lead-base	18,512	19,941
Tin-base	39	39
Total	18,551	19,980
Grand total	20,803	22,339

Form of recovery	1963	1964
In antimonial lead [1]	14,874	16,199
In other lead alloys	5,904	6,110
In tin-base alloys	25	30
Total	20,803	22,339
Value (millions)	$14.5	$18.9

[1] Includes 384 tons of antimony recovered in antimonial lead from secondary sources at primary plant in 1963 and 303 tons in 1964.

TABLE 5.—Byproduct antimonial lead produced at primary lead refineries in the United States

(Short tons)

Year	Gross weight	Antimony content				
		From domestic ores [1]	From foreign ores [2]	From scrap	Total	
					Quantity	Percent
1955-59 (average)	57,278	1,083	653	1,203	2,939	5.2
1960	30,230	456	200	919	1,575	5.2
1961	35,080	1,010	713	171	1,894	5.4
1962	33,325	1,361	752	136	2,249	6.7
1963	[r] 18,818	836	670	384	1,890	[r] 10.0
1964	24,023	997	695	303	1,995	8.3

[r] Revised.

[1] Includes primary residues and small quantity of antimony ore.

[2] Includes foreign base bullion and small quantities of foreign antimony ore.

CONSUMPTION AND USES

Industrial consumption of primary antimony, as reported to the Bureau of Mines, in the first three quarters of 1964 was considerably lower than in the corresponding periods of 1963, reportedly because of a shortage of supply. In the fourth quarter, supply eased and consumption improved. Use of primary antimony in metal products, principally as an alloying metal, decreased some 900 tons in comparison to 1963, and reflected the increased supply of secondary antimony for this purpose, particularly antimonial lead, as well as the tight supply of primary material. Consumption of antimony in nonmetal products, predominantly in the form of oxide, increased about 250 tons; the major increase was in ceramics and glass, although flameproofing chemicals and pigments also had higher requirements. Use in plastics and rubber products, however, declined significantly.

The change in consumption was also evident in the distribution of materials consumed. While in 1962–63 about 53 percent was used in metal products and 47 percent in nonmetal products, the 1964 consumption was approximately equal for metal and nonmetal products. The main reason for this shift is the increasing use of antimony in flameproofing plastics and fabrics.

TABLE 6.—Industrial consumption of primary antimony in the United States

(Short tons, antimony content)

Year	Class of material consumed						Total
	Ore and concentrate	Metal [1]	Oxide	Sulfide	Residues	Byproduct antimonial lead	
1955-59 (average)	620	4,852	6,051	102	532	1,735	13,892
1960	226	5,892	6,033	78	386	656	13,271
1961	106	4,994	5,450	69	355	1,723	12,697
1962	137	6,126	6,642	68	366	2,113	15,452
1963	266	7,124	7,173	71	392	1,506	16,532
1964	252	6,050	7,325	73	447	1,692	15,839

[1] Includes antimony in imported alloys.

TABLE 7.—Industrial consumption of primary antimony in the United States, by class of material produced

(Short tons, antimony content)

Product	1955-59 (average)	1960	1961	1962	1963	1964
Metal products:						
Ammunition	7	(1)	(1)	(1)	(1)	15
Antimonial lead [2]	4,560	4,398	4,708	6,090	6,462	5,952
Bearing metal and bearings	876	803	737	682	992	804
Cable covering	177	146	141	114	101	49
Castings	79	72	53	64	49	50
Collapsible tubes and foil	25	17	24	112	72	53
Sheet and pipe	238	202	147	127	81	99
Solder	116	130	97	172	188	149
Type metal [2]	940	580	448	429	652	513
Other	145	148	152	271	199	167
Total [2]	7,163	6,496	6,507	8,061	8,796	7,851
Nonmetal products:						
Ammunition primers	13	11	15	14	15	17
Fireworks	33	33	20	23	36	47
Flameproofing chemicals and compounds	970	1,177	1,138	1,215	1,601	1,626
Ceramics and glass	1,829	1,640	1,223	1,146	1,465	1,649
Matches	20	17	(1)	9	5	(1)
Pigments	1,211	1,282	845	1,161	1,009	1,173
Plastics	873	1,013	1,228	1,269	1,352	1,289
Rubber products	200	238	287	460	597	492
Other	1,580	1,364	1,434	2,094	1,656	1,695
Total	6,729	6,775	6,190	7,391	7,736	7,988
Grand total	13,892	13,271	12,697	15,452	16,532	15,839

[1] Included with "Other" to avoid disclosing individual company confidential data.

[2] Includes antimony content of imported antimonial lead consumed, 1955 through 1963. Not available thereafter.

STOCKS

Industrial stocks of primary antimony, as reported to the Bureau of Mines, declined from the 7,100 tons (revised) at the beginning of the year to a low of 5,400 tons at the end of the second quarter, increased to 6,000 tons by the end of the third quarter, and at yearend totaled 7,300 tons. Stocks of oxide, drawn down to 1,400 tons at the end of the second quarter, were built up in the third quarter and especially in the fourth quarter as a result of increased imports. Metal stocks, amounting to 1,200 tons at the end of the second and third quarter, were likewise improved by the addition of Government metal in November.

TABLE 8.—Industry stocks of primary antimony in the United States, December 31

(Short tons, antimony content)

Stocks	1959	1960	1961	1962	1963	1964
Ore and concentrate	2,884	2,356	850	1,450	1,970	1,647
Metal	1,422	1,346	1,680	1,599	1,420	1,433
Oxide	1,659	2,187	2,398	1,895	1,861	2,895
Sulfide	115	94	107	90	81	81
Residues and slags	685	938	873	999	1,081	935
Antimonial lead [1]	373	242	538	403	r 651	309
Total	7,138	7,163	6,446	6,436	r 7,064	7,300

r Revised.

[1] Inventories from primary sources at primary lead smelters only.

PRICES

The developing short supply of primary antimony in both the United States and foreign areas was reflected in rising prices of domestic and imported antimony materials. On January 20, 1964, the price of imported metal, 99.6 percent, duty paid, New York, in 5-ton lots, was quoted at 36.5 to 37 cents per pound and had increased to a nominal quotation of 54 to 60 cents per pound by the end of the second quarter and continued at this level the remainder of the year.

The price of domestic metal, RMM brand, 99.5 percent, case lots, f.o.b., Laredo, Tex., after holding at 32.5 cents per pound since April 1961, was increased on January 20 to 35.5 cents and to 44 cents per pound on June 23, where it continued throughout the remainder of the year. The New York equivalent price was 1.75 cents per pound higher. Prices of antimony materials also increased during the first half of the year and the range in price for the various materials is shown in table 9.

TABLE 9.—Antimony price ranges in 1964

Type of antimony:		*Price*
Domestic metal [1]	cents per pound	32.50 to 44.00
Foreign metal [2]	do	33.50 to 60.00
Antimony trioxide [3]	do	30.00 to 60.00
Antimony ore,[3] 50–55 percent	dollars per short-ton unit	3.90 to 8.50
Antimony, minimum 60 percent	do	4.50 to 8.75
Antimony ore, minimum 65 percent	do	4.75 to 9.40

[1] RMM brand, f.o.b., Laredo, Tex.
[2] Duty-paid delivery, New York.
[3] Quoted in E&MJ Metal and Mineral Markets.

FOREIGN TRADE

Imports.—General imports of antimony in various forms totaled 16,700 tons compared with 17,800 tons received in 1963. Imports of ore and concentrates increased 9 percent and oxide imports were 50 percent above the 1963 level. Metal imports, however, declined 40 percent. Ore and concentrates were primarily supplied by Mexico, 37 percent; Bolivia, 20 percent; and the Republic of South Africa, 37 percent. Honduras, Thailand, and South Korea were new suppliers in 1964; Yugoslavia was the largest metal supplier with 50 percent of the total, and Mexico, Peru, Belgium-Luxembourg, United Kingdom, and Thailand were the other significant sources in 1964. Belgium-Luxembourg and the United Kingdom each supplied about 37 percent of the total oxide imports and Canada, France, Pakistan, and West Germany also supplied significant amounts of oxide during the year.

Exports.—Exports of antimony during 1964 totaled 807 tons, of which 387 tons was as ores, 401 tons as metal and crude alloys, and 19 tons in semifabricated forms. Belgium and Luxembourg, Japan, and France, in descending order of importance, received over 98 percent of the ores. France, Japan, and Pakistan received 84 percent of the exports of metal and crude alloys. Of the total exports, France received 38 percent; Japan, 23 percent; Belgium-Luxembourg, 23 percent; Pakistan, 7 percent; and the remaining 9 percent was divided among 10 countries.

TABLE 10.—U.S. imports[1] of antimony, by countries

Year and country	Antimony ore			Needle or liquated antimony		Antimony metal		Antimony oxide	
	Short tons (gross weight)	Antimony content		Short tons (gross weight)	Value (thousands)	Short tons	Value (thousands)	Short tons (gross weight)	Value (thousands)
		Short tons	Value (thousands)						
1955–59 (average)	15,723	6,435	$1,498	86	$38	4,433	$2,124	1,856	[2]$765
1960	16,406	6,455	1,214	24	11	5,437	2,495	2,368	972
1961	16,204	6,713	1,389	13	6	4,912	2,347	1,980	935
1962	20,122	8,602	2,168	17	8	4,740	2,309	2,910	1,391
1963:									
North America:									
Canada	--------	--------	--------	--------	--------	(3)	15	--------	--------
Guatemala	51	31	9	--------	--------	--------	--------	--------	--------
Mexico	13,163	3,999	732	--------	--------	338	132	--------	--------
Total	13,214	4,030	741	--------	--------	338	147	--------	--------
South America:									
Bolivia	1,567	982	317	--------	--------	--------	--------	6	2
Brazil	44	30	11	--------	--------	--------	--------	--------	--------
Chile	962	638	225	--------	--------	--------	--------	--------	--------
Peru	183	133	37	--------	--------	210	88	--------	--------
Total	2,756	1,783	590	--------	--------	210	88	6	2
Europe:									
Belgium-Luxembourg	--------	--------	--------	15	8	1,091	594	782	415
France	--------	--------	--------	--------	--------	82	47	274	131
Germany, West	--------	--------	--------	--------	--------	--------	--------	11	5
Netherlands	--------	--------	--------	--------	--------	--------	--------	8	4
Poland and Danzig	--------	--------	--------	--------	--------	24	12	--------	--------
Spain	--------	--------	--------	--------	--------	55	22	--------	--------
United Kingdom	--------	--------	--------	7	3	1,234	654	1,008	481
Yugoslavia	--------	--------	--------	--------	--------	2,569	1,347	--------	--------
Total	--------	--------	--------	22	11	5,055	2,676	2,083	1,036
Asia: Thailand	--------	--------	--------	--------	--------	54	22	--------	--------
Africa: South Africa, Republic of	6,837	3,971	1,344	--------	--------	39	25	--------	--------
Grand total	22,807	9,784	2,675	22	11	5,696	2,958	2,089	1,038
1964:									
North America:									
Canada	--------	--------	--------	--------	--------	(3)	24	113	121
Honduras	15	10	2	--------	--------	--------	--------	--------	--------
Mexico	12,652	3,937	633	--------	--------	332	214	--------	--------
Total	12,667	3,947	635	--------	--------	332	238	113	121
South America:									
Bolivia	3,240	2,128	919	--------	--------	43	7	--------	--------
Chile	562	357	147	--------	--------	--------	--------	--------	--------
Peru	288	180	86	--------	--------	425	217	--------	--------
Total	4,090	2,665	1,152	--------	--------	468	224	--------	--------
Europe:									
Austria	--------	--------	--------	4	3	--------	--------	--------	--------
Belgium-Luxembourg	--------	--------	--------	--------	--------	302	278	1,168	1,362
France	--------	--------	--------	--------	--------	--------	--------	248	237
Germany, West	--------	--------	--------	--------	--------	(3)	1	310	324
Hungary	--------	--------	--------	--------	--------	--------	--------	11	8
Netherlands	--------	--------	--------	--------	--------	--------	--------	9	10
Switzerland	--------	--------	--------	--------	--------	--------	--------	6	8
United Kingdom	--------	--------	--------	27	18	470	381	1,140	885
Yugoslavia	--------	--------	--------	--------	--------	1,712	1,384	--------	--------
Total	--------	--------	--------	31	21	2,484	2,044	2,892	2,834

See footnotes at end of table.

TABLE 10.—U.S. imports[1] of antimony, by countries—Continued

Year and country	Antimony ore			Needle or liquated antimony		Antimony metal		Antimony oxide	
	Short tons (gross weight)	Antimony content		Short tons (gross weight)	Value (thousands)	Short tons	Value (thousands)	Short tons (gross weight)	Value (thousands)
		Short tons	Value (thousands)						
Asia:									
Japan								39	34
Korea, South	140	85	36						
Pakistan								83	30
Thailand	55	28	17			118	73		
Total	195	113	53			118	73	122	64
Africa: South Africa, Republic of	6,528	3,951	1,454					4	3
Grand total	23,480	10,676	3,294	31	21	3,402	2,579	3,131	3,022

[1] Data are general imports; that is, they include antimony imported for immediate consumption plus material entering the country under bond. Table does not include antimony contained in lead-silver ores.

[2] 1957 data known to be not comparable with other years.

[3] Less than ½ unit.

Source: Bureau of the Census.

TABLE 11.—U.S. imports for consumption of antimony[1]

Year	Antimony ore			Needle or liquated antimony		Antimony metal		Type metal and antimonial lead[2] (short tons)	Antimony oxide	
	Short tons (gross weight)	Antimony content		Short tons (gross weight)	Value (thousands)	Short tons	Value (thousands)		Short tons (gross weight)	Value (thousands)
		Short tons	Value (thousands)							
1955-59 (average)	15,723	6,435	$1,498	88	$39	4,421	$2,120	813	1,854	[3] $764
1960	16,406	6,455	1,214	24	11	5,437	2,495	645	2,368	972
1961	16,204	6,713	1,389	13	6	4,912	2,347	665	1,980	935
1962	20,122	8,602	2,168	17	8	4,720	2,300	1,064	2,910	1,391
1963	22,807	9,784	2,675	22	11	5,717	2,968	[4] 552	2,089	1,038
1964	23,480	10,676	3,294	31	21	3,307	2,481	([5])	3,131	3,022

[1] Does not include antimony contained in lead-silver ore.

[2] Estimated antimony content; for gross weight and value, see Lead chapter.

[3] 1957 data known to be not comparable with other years.

[4] Data not comparable with earlier years.

[5] No longer separately classified.

Source: Bureau of the Census.

WORLD REVIEW

Bolivia.—Production of antimony, predominantly as hand-sorted, high-grade ore, increased during the year under the incentive of high price and strong demand. Empresa Minera Unificada, S.A. (EMUSA), operating 2 large mines and 10 smaller mines in southern Bolivia, increased output some 25 percent to a monthly rate of 500 tons of ore. A flotation concentrator was being installed in the two larger mines with expectation of doubling the monthly production rate early in 1965. Churquini Enterprises, Inc., owned by Metal Traders, Inc., New York, operates the most important single producer in Bolivia as well as one of the small mines. The remainder of the ore is derived from several small and medium sized mines privately owned or leased, with the Banco Minero de Bolivia acting as agent for the individual owners and operators.

Canada.—Output of antimony increased 7 percent compared with that of 1963. All of the antimony was produced by the Consolidated Mining and Smelting Company of Canada, Ltd. The lead concentrates smelted at Trail, British Columbia, from company mines and custom smelting, contain antimony roughly equivalent to 1 percent of the lead produced. The antimony is recovered principally as an antimonial-lead alloy by treatment of drosses and residues of the lead smelter-refinery complex.

The improved market for antimony resulted in widespread exploration and development of antimony properties in British Columbia, Nova Scotia, and New Brunswick with prospects of production from some of the developments in 1965.

China.—Information concerning the antimony industry in China was sparse during the year. Production was estimated to have continued at a high level. Offerings of antimony on the non-Communist market have been selective and substantially below the marketing level prior to 1963.

Japan.—Production of antimony from local ore increased significantly in 1964. The Nakase mine of Nippon Seiko Co. is essentially the only producer. The 40-percent antimony content of the concentrates is used in the production of oxide, sulfide, and crude antimony. A small quantity was refined to metal beginning in 1963.

Mexico.—Cia Mra. y Refinadora Mexicana, S.A., was the largest producer of ores, all of which was shipped to the Laredo refinery of National Lead Co. Numerous small mines operated intermittently and sold ores to National Lead Co. The Monterey smelter, owned by American Smelting and Refining Company before Mexicanization, produced antimony metal as a byproduct. The antimony content of ores exported to the U.S. decreased, but receipts of metal by the U.S. increased in relation to 1963.

Morocco.—The largest producer was Omnium de Gérance Industrielle et Minierè. Several of the antimony mines, after a shutdown of several years, were being reopened under present market demand in the European area.

South Africa, Republic of.—Production of antimony concentrate and cobbed ore, all from the Consolidated Murchison (Transvaal) Goldfields and Development Co., Ltd., totaled 23,600 tons, a 15-percent increase over that of 1963. The new shaft, started in May 1963, was scheduled for completion in mid-1965 to provide facilities for development of the new ore-zone which should add substantially to the ore reserve for the expanded mill capacity. The concentrating plant milled about 199,000 tons of ore in 1964, compared with 188,000 tons in 1963.

Thailand.—The Bansong mine operated by Siamerican Mining Enterprise Co., Ltd., in south Thailand, operated at a rate of some 200 tons of ore per month and export of metal to the U.S. was approxi-

TABLE 12.—World production of antimony (content of ore except as indicated) by countries [1]

(Short tons)

Country	1955–59 (average)	1960	1961	1962	1963	1964 [p]
North America:						
Canada [2]	804	826	666	966	801	859
Guatemala (U.S. imports)	[3] 53	119	71	32	31	----------
Mexico [4]	4,323	4,664	3,978	5,257	5,320	5,278
United States	663	635	689	631	645	632
Total	5,843	6,244	5,404	6,886	6,797	6,769
South America:						
Bolivia (exports) [4]	6,090	5,872	7,430	7,331	8,337	10,626
Peru [4]	941	901	870	575	815	677
Total	7,031	6,773	8,300	7,906	9,152	11,303
Europe:						
Austria	511	676	668	767	548	585
Czechoslovakia [e]	1,800	1,800	1,800	2,200	2,200	2,200
France	80	----------	----------	----------	110	[5] 110
Italy	271	238	276	369	266	376
Spain	216	243	190	175	65	66
U.S.S.R. [e]	5,800	6,300	6,300	6,600	6,700	6,700
Yugoslavia (metal)	1,981	2,657	2,715	2.966	2,933	3,008
Total [e]	10,700	11,900	11,900	13,100	12,800	13,000
Asia:						
Burma [4]	110	180	175	138	126	[e] 110
China [e]	15,000	16,500	16,500	16,500	16,500	16,500
Iran [6]	108	[e] 55	----------	----------	----------	----------
Japan	418	299	215	190	212	554
Pakistan	[7] 100	69	15	75	9	90
Ryukyu Islands	13	159	112	----------	----------	----------
Sarawak	----------	----------	----------	----------	----------	86
Thailand	17	----------	25	19	676	1,399
Turkey	1,441	1,507	1,502	1,962	1,981	1,915
Total [e]	17,200	18,800	18,500	18,900	19,500	20,700
Africa:						
Algeria	1,700	886	720	149	----------	----------
Morocco	375	358	406	449	744	1,719
South Africa, Republic of	12,775	13,537	11,804	11,697	12,410	14,200
Southern Rhodesia	127	100	68	61	66	49
Total	14,977	14,881	12,998	12,356	13,220	15,968
Oceania: Australia	538	172	132	74	83	303
World total (estimate) [1]	56,300	58,800	57,200	59,200	61,600	68,000

[e] Estimate. [p] Preliminary.

[1] This table incorporates some revisions. Data do not add exactly to totals shown because of rounding where estimated figures are included in the detail.

[2] Antimony content of smelter products exclusively from mixed ores.

[3] Average annual production 1957–59.

[4] Includes antimony content of smelter products derived from mixed ores.

[5] 1963 data.

[6] Year ended March 20 of year following that stated.

[7] Average annual production 1956–59.

mately double that of 1963. A small amount of high-grade hand cobbed ore was exported.

Turkey.—Antimony production was principally that of the Özdemir Antimuan Madenieri, Ltd., Sirketi near Turhal, and consisted of mill concentrate and hand sorted ore. A recently discovered vein of antimony ore near Niğde produced for export a small tonnage of high-grade ore for testing in 1964. Construction was begun on a flotation mill near Istanbul by Cevher-Proje-Tesis which was expected to produce 3 to 4 tons of 60 percent antimony sulfide concentrate per day by mid-1965.

TECHNOLOGY

The increasing use of high purity antimony in the manufacture of intermetallic compounds for semiconductor use and in other chemical applications has expanded chemical research. The use of solvent extraction and in some cases determination of the more commonly encountered metals is a technique which is now widely accepted by analytical chemists, and results of investigations were reported.[2]

A comprehensive report on development and data relating to differential flotation of antimony ores was published,[3] and the role of antimony in storage battery grids was examined and the results and conclusions of the study reported.[4] U.S. patents were issued relative to a process for preparing crystalline antimony oxychloride[5] and preparation of solutions of polymers in a solvent composed of antimony trichloride and an acid diluent.[6]

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[2] Biryukov, N. D. Extraction of Antimony by Electrolysis From Solutions of Antimony Thio Salts. Trans. Zhurnal Prikladnoi Khimii (Academy of Sciences of the U.S.S.R.), v. 35, No. 5, May 1962, pp. 1048–1057.

Green, H. Separation Using Solvent Extraction. Metallurgia (Manchester, England), v. 70, No. 420, October 1964, pp. 201–204.

Philips Research Reports. Crystal Chemistry and Some Magnetic Properties of Oxidic Spinels Containing Pentavalent Antimony. No. 3 Supp., 1964, ch. 9, pp. 105–120.

[3] Oberbillig, Ernest. Flotation of Antimony Ores. Min. Mag. (London), v. 110, No. 7, July 1964, pp. 35–45.

[4] Burbank, Jeanne. The Role of Antimony in Positive Plate Behavior in the Lead-Acid Cell. J. Electrochem. Soc., v. 111, No. 10, October 1964, pp. 1112–1116.

[5] Banks, Clarence K., and Leonard M. Edwards. (assigned to M&T Chemicals, Inc., New York). Novel Process for Preparing Antimony Oxychloride. U.S. Pat. 3,148,943, Sept. 15, 1964.

[6] Parczewski, Krzysztof I. (assigned to Celanese Corporation of America, New York). Terephthalamide Polymer in Solvent Comprising Antimony Trichloride and Acetic or Formic Acid. U.S. Pat. 3,154,512, Oct. 27, 1964.

Van Gorder, Norman, and Amerigo F. Caprio. (assigned to Celanese Corporation of America, New York). Solutions of Polymers in Solvent Comprising Antimony Trichloride and Process for Preparing Same. U.S. Pat. 3,154, 509, Oct. 27, 1964.

Asbestos

By Timothy C. May[1]

⁂

FOR the first time, domestic production of asbestos exceeded 100,000 short tons. California surpassed Vermont in production of chrysotile asbestos. Total U.S. sales were 52 percent higher in volume and 59 percent higher in value than in 1963. The Nation ranked sixth among world producers. Canada continued to be the leading producer with 40 percent of the total output.

TABLE 1.—Salient asbestos statistics

	1955–59 (average)	1960	1961	1962	1963	1964
United States:						
Production (sales) short tons	43,794	45,223	52,814	53,190	[r] 66,396	101,092
Value thousands	$4,733	$4,231	$4,347	$4,677	[r] $5,108	$8,143
Imports for consumption (unmanufactured) short tons	694,088	669,496	616,529	675,953	667,860	739,361
Value thousands	$61,264	$63,345	$58,942	$64,112	$61,739	$72,973
Exports (unmanufactured)[1] short tons	3,223	5,525	3,799	2,949	10,044	27,147
Value thousands	$442	$857	$759	$598	$1,304	$3,199
Exports of asbestos products (value)[1] thousands	$13,683	$13,703	$13,825	$14,274	[r] $16,267	$16,288
Consumption, apparent[2] short tons	734,659	709,194	665,544	726,194	[r] 724,212	813,306
World: Production do	2,065,000	2,440,000	2,770,000	3,050,000	3,210,000	3,540,000

[r] Revised.
[1] Includes reexports.
[2] Measured by quantity produced, plus imports, minus exports.

LEGISLATION AND GOVERNMENT PROGRAMS

The Office of Emergency Planning announced new stockpile objectives of 40,000 short tons for amosite and 13,700 tons for chrysotile.

Under the Agricultural Trade Development and Assistance Act of 1954 (Public Law 480, 83d Cong.), the Department of Agriculture, through the Commodity Credit Corporation (CCC), bartered surplus agricultural commodities for the various types of asbestos. A total of 24,434 tons was acquired under the program in 1964, consisting of 12,905 tons of crocidolite, 11,308 tons of amosite, and 211 tons of chrysotile.

Strategic stockpile inventories on December 31, 1964, were as follows: Amosite, 11,705 tons; chrysotile, 6,224 tons; crocidolite (soft), 1,567 tons. Supplemental and CCC stockpiles consisted of the following: Amosite, 39,918 tons; chrysotile, 3,063 tons; crocidolite (harsh), 40,342 tons. Also, 2,348 tons of nonstockpile grade chrysotile was held in the Defense Production Act stockpile and 40,342 tons of nonobjective crocidolite (harsh) in the Supplemental and CCC stockpiles.

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[1] Commodity specialist.

DOMESTIC PRODUCTION

Asbestos production in the United States was 52 percent more than 1963. Most of the increased production was from California deposits.

Vermont Asbestos Mines Division of Ruberoid Co., Lowell mine, near Hyde Park, Vt., continued as the major producer of chrysotile asbestos.

Three companies reported shipments of chrysotile from Gila County, Ariz.: Asbestos Manufacturing Co. from the Asbestos Peak and Ash Creek mines; Jaquays Mining Corp. from the Regal and Chrysotile mines; and Metate Asbestos Corp. from the Lucky Seven mine. It was reported that Johns-Manville Corp. set up bagging operations at the Metate Asbestos Corp. plant.

California production and shipments of chrysotile were reported by the following companies: Pacific Asbestos Corp. (formerly Jefferson Lake Asbestos Corp.), Calaveras County; Atlas Mineral Corp. and Coalinga Asbestos Co., Fresno County; Asbestos Bonding Co., Napa County; and Union Carbide Corp., Nuclear Division, San Benito County. It was reported that a new mill was placed in operation by the United States Asbestos Co. (formerly a Todd Industries operation) in Coalinga. Plant capacity was rated to exceed 25,000 tons of fiber per year.

Powhatan Mining Co., Baltimore, Md., produced anthophyllite asbestos at the Burnsville mine, Yancey County, N.C.

CONSUMPTION AND USES

Over 96 percent of the chrysotile consumed was short fiber of less than spinning length and was used chiefly in the manufacture of products used in the building construction industry. Asbestos cement products such as pipes, flat or corrugated sheet, roofing or siding shingles, and wallboards utilized the larger quantity of asbestos. The longer and better grades were used in the manufacture of asbestos textiles for use in safety clothing, clutch facings, brake linings, and plastics. Much of the Arizona chrysotile was used for filtering purposes and that produced in California was used in the manufacture of floor tile.

Consumption of crocidolite and amosite represented by imports continued to increase. Imports of crocidolite and amosite in 1964 were 25,000 and 24,000 tons respectively, compared with 11,000 and 22,000 tons in 1963.

PRICES[2]

Quotations for Arizona asbestos, f.o.b. Globe, were listed as follows:

Grade:	Per short ton			
	1963		July 10, 1964	
No. 1 crude	$1,475	$1,650	$1,410	$1,650
No. 2 crude	800	1,000	610	900
AAA	------	------	------	800
Group No. 3 (nonferrous filtering and spinning)	425	500	425	750
Group No. 4 (nonferrous plastic and filtering)	385	420	385	500
Group No. 5 (plastic and filtering)	250	400	250	400
Group No. 7 (refuse and shorts)	58	90	58	90

Canadian (Quebec and British Columbia) chrysotile, f.o.b. mine, and United States (Vermont) chrysotile, f.o.b. mine, remained unchanged from prices quoted in 1962 and 1963. Cassiar (British Columbia) added a new grade, AY.

Canadian (Quebec) chrysotile asbestos prices, f.o.b. mine, were as follows:

Grade:	Per short ton
Crude No. 1	Can$1,410 to Can$1,475
Crude No. 2—Crude run of mine and sundry	610 to 875
No. 3—Spinning fiber	350 to 650
No. 4—Shingle fiber	180 to 245
No. 5—Paper fiber	120 to 150
No. 6—Waste, stucco, or plaster	86
No. 7—Refuse or shorts	40 to 80

Prices for British Columbia chrysotile asbestos, f.o.b. Vancouver, from Cassiar Asbestos Corp., Ltd., were as follows:

Grade:	Per short ton
No. 1 crude (C–1)	Can$1,522
AAA	787
AA	625
A	470
AC	325
AK	220
AS	181
AX	142
Talus	210

Vermont asbestos prices, f.o.b. Hyde Park or Morrisville, remained as follows:

Grade:	Per short ton
Group No. 3—Spinning and filtering	$345 to 402
Group No. 4—Shingle fiber	181 to 320
Group No. 5—Paper fiber	120 to 142
Group No. 6—Waste, stucco, or plaster	86
Group No. 7—Refuse or shorts	40 to 75

Market quotations were not available for African and Australian asbestos because sales were negotiated separately. U.S. Department of Commerce reports show the following figures for imports per short ton:

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[2] Asbestos. V. 46, No. 6, July 1964, p. 48.

	1963	*1964*
Imports:		
Amosite: South Africa, Republic of	$158	$157
Crocidolite:		
Australia	190	197
South Africa, Republic of	212	198

FOREIGN TRADE

Imports of crocidolite were more than double those of 1963, and imports of chrysotile and amosite increased 9 percent each, resulting in a net increase of 11 percent in total imports.

Imports of low-iron spinning-length chrysotile from British Columbia, Canada, increased from 4,698 tons in 1963 to 4,948 tons, and imports of all grades of fiber increased from 14,088 tons to 18,640 tons in 1964.

Of all the chrysotile imported, fiber of less than spinning length accounted for 96 percent.

TABLE 2.—U.S. imports for consumption of asbestos (unmanufactured), by classes and countries

Year and country	Crude (including blue fiber)[1]		Textile fiber [1]		All other		Total	
	Short tons	Value	Short tons	Value	Short tons	Value	Short tons	Value
1963:								
North America: Canada	470	$89,017	13,852	$5,216,206	604,420	$48,706,010	618,742	$54,011,233
Europe:								
Finland	55	2,000	------	----------	398	22,246	453	24,246
Italy [1]	6	7,525	------	----------	------	----------	6	7,525
Portugal [1]	------	----------	------	----------	29	3,193	29	3,193
Yugoslavia	6,331	215,955	------	----------	1,177	45,224	7,508	261,179
Africa:								
Portuguese Western Africa, n.e.c	------	----------	------	----------	20	2,601	20	2,601
Rhodesia and Malawi [1] [2]	2,328	449,231	330	143,117	1,480	303,897	4,138	896,245
South Africa, Republic of [1]	33,172	5,830,022	136	27,845	3,646	673,044	36,954	6,530,911
Oceania: Australia	10	1,896	------	----------	------	----------	10	1,896
Total	42,372	6,595,646	14,318	5,387,168	611,170	49,756,215	667,860	61,739,029
1964:								
North America:								
Canada	4,466	795,546	13,881	5,380,633	648,626	54,404,684	666,973	60,580,863
Mexico	------	----------	------	----------	304	32,995	304	32,995
South America:								
Bolivia	3	4,800	------	----------	------	----------	3	4,800
Venezuela	------	----------	------	----------	624	26,996	624	26,996
Europe:								
Finland	117	4,400	------	----------	934	42,522	1,051	46,922
Italy	------	----------	------	----------	6	7,395	6	7,395
Portugal	------	----------	------	----------	5	560	5	560
Spain	------	----------	------	----------	50	8,374	50	8,374
U.S.S.R	------	----------	------	----------	20	732	20	732
Yugoslavia	2,785	107,148	------	----------	2,081	74,977	4,866	182,125
Africa:								
Mozambique	------	----------	90	37,273	239	41,921	329	79,194
Portuguese Western Africa, n.e.c	------	----------	------	----------	130	10,386	130	10,386
Rhodesia and Malawi [1] [2]	7,633	1,518,126	90	35,719	6,271	1,330,350	13,994	2,884,195
South Africa, Republic of [1]	49,607	8,843,905	------	----------	924	169,208	50,531	9,013,113
Oceania: Australia	475	94,022	------	----------	------	----------	475	94,022
Total	65,086	11,367,947	14,061	5,453,625	660,214	56,151,100	739,361	72,972,672

[1] Data reported by the Bureau of the Census have been adjusted by the Bureau of Mines.
[2] All believed to be from Southern Rhodesia.

Source: Bureau of the Census.

TABLE 3.—U.S. imports for consumption of asbestos, from specified countries, by grades

(Short tons)

Grade	1963			1964		
	Canada	Southern Rhodesia [1]	Republic of South Africa [2]	Canada	Southern Rhodesia [1]	Republic of South Africa [2]
Chrysotile:						
Crudes	470	2,188	452	4,466	7,633	817
Spinning and textile	13,852	330	136	13,881	90	
All other	604,420	1,480	3,646	648,626	6,271	924
Crocidolite (blue)		140	10,776			24,858
Amosite			21,944			23,932
Total	618,742	4,138	36,954	666,973	13,994	50,531

[1] Reported by the Bureau of the Census as Rhodesia and Malawi.
[2] Includes data adjusted by the Bureau of Mines.

Source: Bureau of the Census.

TABLE 4.—U.S. exports and reexports of asbestos and asbestos products

Product	1963		1964	
	Quantity	Value	Quantity	Value
Exports:				
Unmanufactured:				
Crude and spinning fibers short tons	847	$228,666	620	$168,137
Nonspinning fibers do	3,169	506,725	12,887	1,881,195
Waste and refuse do	5,962	553,272	13,312	1,112,664
Total unmanufactured do	9,978	1,288,663	26,819	3,161,996
Products:				
Brake lining and blocks-molded, semimolded, and woven	(1)	4,888,141	(1)	4,808,497
Clutch facing and lining number	2,519,467	1,760,767	2,046,247	1,840.560
Construction materials, n.e.c short tons	[r] 13,163	[r] 3,307,031	12,988	3,204,223
Pipe covering and cement do	4,100	1,607,754	3,951	1,599,039
Textiles, yarn, and packing do	1,496	3,499.384	1,520	3,566,507
Manufactures, n.e.c	(2)	1,183,752	(2)	1,235,055
Total products		[r] 16,246,829		16,253,881
Reexports:				
Unmanufactured:				
Crude and spinning fibers short tons	66	14,651	108	17,725
Nonspinning fibers do			2	660
Waste and refuse do			218	18,861
Total unmanufactured do	66	14,651	328	37,246
Products:				
Construction materials, n.e.c short tons	28	10,637	114	22,496
Pipe covering and cement do	(3)	5,670		
Textiles and yarn do			(3)	122
Manufactures, n.e.c	(2)	3,800	(2)	11,870
Total products		20,107		34,488

[r] Revised.
[1] Values have been summarized; quantities not shown.
[2] Quantity not recorded.
[3] Less than ½ unit.

Source: Bureau of the Census.

WORLD REVIEW

NORTH AMERICA

Canada.—Shipments of asbestos reached an alltime record high. Approximately 1.42 million tons was shipped showing an increase of 11 percent compared with 1963.

Both volume and sales for Cassiar Asbestos Corp., Ltd., were higher than in 1963. Cassiar accounted for approximately 5 percent of the quantity and 10 percent of value of total Canadian exports of asbestos in 1964. During the year the mine produced 705,000 tons of ore, of which 350,000 tons was treated in the rock rejection circuit to eliminate 118,000 tons of rock. Ore and concentrate milled totaled 588,000 tons. An addition to the mill completed in July 1964 provided for production of the new AY grade. Production of fiber was 66,897 tons, an increase of 7 percent over 1963. Diamond drilling was carried out on the Clinton Creek property, Yukon Territory. A preliminary estimate of the ore outlined to date was 12.3 million tons.[3]

Operations at the Canadian Johns-Manville Co., Ltd. Munro mine near Matheson, Ontario, were terminated in August. The Munro mine began commercial production of fiber for asbestos cement in 1950 and was the only producing mine in Ontario. Bulk sampling and drilling were being pursued at the Garrison Township property about 13 miles east of the Munro mine. Also, development and evalution was in progress by Canadian Johns-Manville on its Reeves Township property about 40 miles southwest of Timmins.[4]

The various steps necessary to make a producing mine out of a new discovery, as experienced by Advocate Mines Ltd., at its Baie Verte mine on the northeastern coast of Newfoundland, were described. It was reported that 10 years were required to bring the deposit into production after discovery.[5]

The McAdam Mining Corp. completed a 3-year drilling program on its Roberge Lake property in McCorkill Township, east of Chibougmau, Quebec. It was reported that 40 million tons of chrysotile asbestos ore that can be mined at a profit was found.[6]

Asbestos Corp., Ltd., and Johnson's Co., Ltd., including its subsidiary, Johnson's Asbestos Co., announced an agreement to integrate their operations in the Thetford-Black Lake region of the eastern townships. The Asbestos Corp., Ltd., early in the year, acquired the deposit of Murray Mining Corp., Ltd., in northern Ungava, Quebec. The asbestos deposit is located 40 miles south of Hudson Strait and 1,200 miles north of Montreal.[7]

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[3] Cassiar Asbestos Corp., Ltd., (Toronto). Thirteenth Annual Report, Dec. 31, 1964.

[4] Woodroffe, H. M., H. K. Conn, and S. J. Rice. Asbestos. Min. Eng., v. 17, No. 2, February 1965, p. 121.

[5] Mining in Canada (Winnepeg) Asbestos After a Decade. V. 37, No. 8, August 1964, pp. 12–15.

World Mining. Advocate Asbestos—Canada's New Producer. V. 17, No. 10, September 1964, pp. 49–51.

[6] Northern Miner (Toronto). McAdam Considering Production Plans for Asbestos Show. V. 50, No. 33, Nov. 5, 1964, pp. 1, 7.

[7] Engineering and Mining Journal. Asbestos Corp. Acquires Two Mining Companies, V. 165, No. 4, April 1964, p. 138.

TABLE 5.—World production of asbestos, by countries [1] [2]

(Short tons)

Country [1]	1955–59 (average)	1960	1961	1962	1963	[p] 1964
North America:						
Canada (sales)	1,019,983	1,118,456	1,173,695	1,215,814	1,276,609	1,416,650
United States (sold or used by producers)	43,794	45,223	52,814	53,190	66,396	101,092
Total	1,063,777	1,163,679	1,226,509	1,269,004	1,343,005	1,517,742
South America:						
Argentina	508	----------	----------	----------	220	[3] 220
Bolivia (exports	73	66	57	56	10	----------
Brazil	3,420	[e] [4] 3,900	[e] [4] 3,400	[e] [4] 4,900	[5] 1,440	[3] [5] 1,440
Venezuela	5,891	4,333	650	----------	----------	----------
Total	9,892	8,299	[e] 4,100	[e] 5,000	1,670	1,660
Europe:						
Austria	----------	66	564	503	638	----------
Bulgaria	1,152	1,200	1,200	[e] 1,100	[e] 1,100	[e] 1,100
Finland [6]	9,108	10,534	10,340	10,869	10,108	11,611
France	17,292	28,662	30,746	28,364	26,645	24,250
Italy	42,141	60,532	62,804	61,233	63,418	75,573
Portugal	63	144	21	----------	29	----------
Spain	3	4	11	----------	----------	----------
U.S.S.R. [e]	519,000	660,000	880,000	1,100,000	1,200,000	1,300,000
Yugoslavia	5,060	5,970	6,709	7,400	9,074	9,280
Total [e]	595,000	770,000	990,000	1,210,000	1,310,000	1,420,000
Asia:						
China [e]	47,000	90,000	100,000	100,000	110,000	130,000
Cyprus	15,325	23,316	16,207	22,391	19,962	13,037
India	1,527	1,886	1,624	1,865	2,989	3,271
Japan	10,972	17,042	18,799	15,407	18,210	17,979
Korea, South	66	696	341	1,333	2,120	[e] 1,300
Philippines	[7] 56	36	83	1,037	421	586
Taiwan	197	485	44	525	604	526
Turkey	449	238	496	709	409	1,015
Total [e]	75,500	135,000	138,000	145,000	155,000	170,000
Africa:						
Bechuanaland	1,608	1,282	1,924	2,375	2,368	2,161
Kenya	119	117	151	212	78	204
Morocco	228	----------	----------	----------	----------	----------
Mozambique	179	22	162	370	----------	----------
South Africa, Republic of	154,348	175,867	194,834	221,302	205,744	215,592
Southern Rhodesia	120,634	133,963	161,610	142,196	142,255	153,451
Swaziland	28,657	32,027	30,792	32,830	33,350	39,862
United Arab Republic (Egypt)	202	496	254	606	192	[3] 192
Total	305,975	343,774	389,727	399,891	383,987	411,462
Oceania:						
Australia	12,764	15,613	16,746	18,416	13,374	[e] 16,200
New Zealand	373	319	373	457	439	[3] 439
Total	13,137	15,932	17,119	18,873	13,813	[e] 16,650
World total (estimate) [1] [2]	2,065,000	2,440,000	2,770,000	3,050,000	3,210,000	3,540,000

[e] Estimate. [p] Preliminary.

[1] Asbestos is also produced in Czechoslovakia, Eritrea, North Korea, and Rumania. No estimates for these countries are included in the total, as production is believed to be negligible.

[2] This table incorporates some revisions. Data do not add to totals shown because of rounding where estimated figures are included in the detail.

[3] 1963 data.

[4] Data represents fiber.

[5] Bahia only.

[6] Includes asbestos flour.

[7] Data for year 1959 only.

TABLE 6.—Canada: Shipments of asbestos, by grades

(Short tons)

Grade	1960	1961	1962	1963	1964
Quebec:					
Crude No. 1, 2, and other	330	163	205	218	218
Milled group:					
3 (spinning)	32, 190	29, 296	30, 374	23, 160	31, 376
4 (shingle)	294, 092	339, 082	355, 121	292, 080	319, 629
5 (paper)	156, 901	179, 852	161, 952	154, 456	188, 672
6 (stucco)	179, 361	193, 467	209, 572	224, 209	232, 382
7 (refuse)	445, 509	423, 116	451, 521	456, 209	507, 003
8 (sand)	10, 073	8, 719	7, 069	7, 986	5, 602
Newfoundland, Ontario, and British Columbia	(1)	(1)	(1)	118, 291	131, 768
Total all grades	1, 118, 456	1, 173, 695	1, 215, 814	1, 276, 609	1, 416, 650

[1] Included with Quebec.

Source: Dominion Bureau of Statistics.

A description of the history of mining methods at the Jeffrey mine of the Canadian Johns-Manville Co., Ltd., at Asbestos, Quebec, was published. The Jeffrey deposit has been in operation since 1881. Reasons for the conversion of mining operations from open pit to underground followed by the reversal to open pit are noted.[8]

It was reported that mine production and sales at the Black Lake property operated by Lake Asbestos of Quebec, Ltd., during the first months of 1964 were at an alltime high. Asbestos fiber produced and shipped for the 6-month period was 11 percent and 14 percent above that of the corresponding period in 1963.[9]

SOUTH AMERICA

Brazil.—Asbestos was mined in the southeastern part of the Macacos quadrangle and occurs in serpentinite as cross fiber veinlets and as slip fiber.[10]

EUROPE

Greece.—Kennecott Copper Corp. sold the concession rights on the Kozani asbestos mine to the Greek state-owned Industrial Development Corporation for $20,000. A pilot plant was built at the deposit, but it was never placed in commercial production.[11]

Yugoslavia.—Asbestos was discovered in the Ibar Massive area between Kraljevo, Servia, and Skopje, Macedonia. It is reported that the deposit contains about 40 million tons of ore containing about 1.13 percent fiber. The only working mine in Yugoslavia is at Korlaca in the same area.[12]

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[8] Brigham, S. K., and G. A. Piché. Mining Methods at Jeffrey Mine. Mining in Canada (Winnipeg), v. 37, No. 12, December 1964, pp. 7–13.
Skillings' Mining Review. History of Mining Methods Employed at Jeffrey Asbestos Mine, Quebec. V. 53, No. 15, Apr. 11, 1964, pp. 4, 18–19.

[9] Northern Miner (Toronto). United Asbestos Net Higher—Sales at Record. V. 50, No. 20, Aug. 6, 1964, p. 12.

[10] Pomerene, J. B. Geology and Ore Deposits of the Belo Horizonte, Ibirite, and Macacos Quadrangles, Minas Gerais, Brazil. U.S. Geological Survey Professional Paper 341–D, 1964, p. 74.

[11] Mining Journal (London). Kennecott Sells Greek Asbestos Rights. V. 263, No. 6729, August 1964, p. 98.

[12] Engineering and Mining Journal. V. 165, No. 8, August 1964, p. 158.

ASIA

China.—The expansion of one of China's largest asbestos mines in Szechwan Province was reported. When completed, mining, transportation, and ore dressing will be mechanized.[13]

Japan.—In April 1964 a 5 percent duty was imposed on shipments valued at less than $917 per metric ton. Asbestos was produced almost exclusively in Hokkaido by Nozawa Asbestos Cement Co. and Yamabe Asbestos Co.

AFRICA

South Africa, Republic of.—During 1964, 215,592 tons of asbestos was produced consisting of 77,276 tons of amosite, 35,921 tons of chrysotile, and 102,395 tons of crocidolite. Total exports amounted to 207,470 tons.

Cape Asbestos South Africa (Pty.), Ltd., completed a dust-free milling plant at the Penge mine, the largest producer of amosite asbestos.

The major producers of Cape Blue asbestos (crocidolite), Cape Blue Mines (Pty.), Ltd., Griqualand Exploration & Finance, Ltd., and Wandrag Asbestos (Pty.) formed an association so that there will be one fully representative body for the whole industry. Standardization of grades and nomenclature of Cape Blue asbestos will be developed.[14]

TABLE 7.—Republic of South Africa: Asbestos production, by varieties and sources

(Short tons)

Variety and source	1960	1961	1962	1963	1964
Amosite (Transvaal)	68, 630	69. 234	74, 883	77, 618	77, 276
Chrysotile (Transvaal)	29, 471	31, 726	29, 993	28, 928	35, 921
Blue (Transvaal)	11, 185	11, 176	14, 296	11, 205	10, 304
Blue (Cape)	66, 567	82, 624	102, 034	87, 965	92, 091
Tremolite (Transvaal)	14	74	96	28	----------
Total	175, 867	194, 834	221, 302	205, 744	215, 592

TABLE 8.—Republic of South Africa: Asbestos exports by varieties and sources

(Short tons)

Variety and source	1960	1961	1962	1963	1964
Amosite (Transvaal)	68, 187	67, 863	69, 659	72, 899	81, 763
Chrysotile (Transvaal)	25, 338	25, 094	27, 538	16, 109	28, 573
Blue (Transvaal)	9, 122	12, 025	11, 867	9, 309	10, 709
Blue (Cape)	72, 152	75, 702	75, 106	85, 535	97, 135
Tremolite (Transvaal)	11	4	----------	9	----------
Total	174, 810	180, 688	184, 170	183, 861	218, 180

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[13] Engineering and Mining Journal. China Mechanizes Mine, Increases Asbestos Output. V. 165, No. 6, June 1964, p. 255.

[14] South African Mining and Engineering Geology (Johannesburg). Cape Blue Asbestos Association. V. 75, pt. 1, No. 3711, Mar. 20, 1964, p. 627.

Southern Rhodesia.—Rhodesian & General Asbestos Corp. (Pvt.), Ltd., of Bulawayo announced that the Cementation Co. (Rhodesia) would sink the new King Section shaft at Gath's mine. The concrete-lined shaft will be 20 feet in diameter and 1,458 feet deep.[15]

As part of the first stage of the development of the new Pangani mine near Filabusi, more than 1 million tons of overburden was removed. Asbestos Investments (Pty.), Ltd., plans to remove 5 million tons of overburden, uncovering about 4 million tons of asbestos ore.[16]

TABLE 9.—Southern Rhodesia: Chrysotile asbestos production

Year	Short tons	Value (thousands)	Year	Short tons	Value (thousands)
1960	133,963	$20,888	1963	142,255	$16,791
1961	161,610	24,453	1964	153,451	19,174
1962	142,196	20,467			

OCEANIA

Australia.—Numerous outcrops of asbestos were reported at Baryulgel, 40 miles northwest of Grafton, New South Wales. Asbestos Mines (Pty.), Ltd., has been working in the area.[17]

TECHNOLOGY

A Conference on the Biological Effects of Asbestos sponsored by the New York Academy of Sciences was held in New York City in October. Papers were presented in the biological and physical sciences by leading investigators from many countries concerned with the effects of asbestos inhalation on health. Panel discussions covered asbestos materials in modern technology, living tissue and mineral matter, experimental asbestosis, asbestosis in industrial populations, dust controls and standards, asbestos and neoplasia, and pulmonary function in asbestosis.[18]

Chrysotile fibers were dehydrated hydrothermally, and the resulting pseudomorphs studied by x-ray rotation photographs. Initial products were forsterite and distorted material.[19]

Electron micrographs of individual fibers of chrysotile have shown it to have a tubular morphology. Chrysotile crudes from Lake Asbestos of Quebec, Ltd., Black Lake, Quebec; Johns-Manville, Asbestos, Quebec; Bell Asbestos Mines, Ltd., Thetford mine, Quebec; Asbestos Corp., Ltd., Vimy Ridge, Quebec; and Cassiar Asbestos Corp., Ltd., McDame Lake, British Columbia, were subjected to ultrasonic cleaning treatment. All samples liberated an ultrafine material when subjected to ultrasonic irradiation. The fine material fills the interstices between fibers.[20]

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[15] Mining Journal (London). Asbestos Mine Contract in S. Rhodesia. V. 263, No. 6744, Nov. 20, 1964, p. 377.

[16] South African Mining and Engineering Journal. Stripping Overburden at Pangani Asbestos Mine, v. 75, pt. 1, No. 3, No. 3718, May 8, 1964, p. 1001.

[17] Mining Journal (London). Barryulgel Asbestos. V. 262, No. 6720, June 5, 1964, p. 449.

[18] New York Academy of Sciences, Section of Biological and Medical Sciences. Conference on Biological Effects of Asbestos. New York, Oct. 19–21, 1964.

[19] Ball, M. C., and H. F. W. Taylor. The Dehydration of Chrysotile in the Air and Under Hydrothermal Conditions. Mineralogical Magazine (London), v. 33, No. 261, June 1963, pp. 467–483.

A lenticular mineralization of asbestos was found along an outcrop 15 miles long in Chamoli, India. Chemical analysis indicates the material to belong to either the type actinolite or cummingtonite.[21]

Production and milling of amosite asbestos from the Penge mine in Transvaal, Republic of South Africa, was discussed. Dry milling of asbestos rock gave rise to problems of dust extraction and disposal of mill tailings. The mill has been arranged for almost totally enclosed conveying and handling. Hammer and fiberizing mills are enclosed, leakproof, and completely air swept.[22]

Research was conducted on the synthesis of fibrous materials that may be suitable for use as natural asbestos substitutes.[23]

The sterilization of liquids by filtration through an asbestos pad was discussed. The most important factor in this type of cold sterilization is the asbestos filter sheet, which should be acid treated and constantly checked to meet high standards of low leachable Ca and Fe content. Finest grades of asbestos filter sheet are used for the retention of bacteria or pyrogens.[24]

Friction matting of asbestos yarns and copper wire was developed for clutch and brake applications for construction machinery and other heavy automotive equipment. The matting offers high spin strength at low wear rates.[25]

The effect of sodium silicate on the filtration rate of a 4K chrysotile fiber that was ball milled and passed through a disintegrator was investigated.[26]

Procedures in the testing of asbestos at the Quebec Asbestos Mining Association Research Testing Laboratory at the University of Sherbrooke were discussed. The review of actual test procedures and apparatus, and the development of new testing techniques for a thorough evaluation of the physical properties and strength-imparting characteristics of asbestos fibers constitutes the main work load of the laboratory.[27]

Major operating and maintenance problems encountered since the start-up in 1962 of a 30,000-ton-per-day skipway, at the Jeffrey mine, Asbestos, Quebec, and the steps taken to overcome them were discussed.[28]

Chemical and physical properties of crocidolite asbestos were described and the manner in which these properties may be used to produce a wide range of reinforced plastic moldings and laminates was illustrated.[29]

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[20] Martinez, E., and J. Comer. The Concentration and Study of the Interstitial Material in Chrysotile Asbestos. Am. Mineralogist, v. 49, Nos. 1 and 2, 1964, pp. 153–157.

[21] Prakash, D. and I. K. Dalela. On the Occurrence of Asbestos in Chamoli, U.P. India. Am. Mineralogist, v. 49, Nos. 3 and 4, March–April 1964, pp. 424–427.

[22] South African Mining & Engineering Journal (Johannesburg). Penge Solves Asbestos Dust Problem. V. 75, No. 3709, Mar. 6, 1964, pp. 487–488, 490.

[23] Johnson, R. C., W. H. Warwick, H. R. Shell. Synthesis and Some Properties of Fibrous Silicon Nitride. BuMines Rept. of Inv. 6467, 1964, 25 pp.

[24] Vogel, G. P., Sterile Filtration. American Perfumer Cosmetology, v. 79, No. 6, 1964, pp. 65–66; Chem. Abs., v. 61, No. 6, Sept. 14, 1964, col. 6871.

[25] Materials in Design Engineering. V. 59, No. 2 February 1964, p. 154.

[26] Martinez Edward. The Effect of Sodium Silicate on the Filtration Rate of Asbestos Fiber. Canadian Min. and Met. Bull. (Montreal), v. 57, No. 630, October 1964, pp. 1042–1044.

[27] Paré, J. J. The O.A.M.A. Research Testing Laboratory and Its Relation to the Asbestos Mining Industry. Canadian Min. and Met. Bull. (Montreal), v. 57, No. 630, October 1964, pp. 1045–1049.

[28] Fletcher, J. M. Jeffrey Skipway-Operation and Maintenance. Canadian Min. and Met. Bull. (Montreal), v. 57, No. 628, August 1964, pp. 842–848.

The properties imparted by using asbestos in the manufacture of a new reinforced thermoplastic laminating material were described. The inorganic fiber content imparts heat and chemical resistance, impact strength, dimensional stability, low coefficient of expansion, and resistance to creep.[30]

The effect of ultrasonic energy transmitted through a liquid on chrysotile asbestos was investigated. Ultrasonic energy was effective in fiberization of chrysotile crudes as well as standard grades of milled asbestos fibers. It was found that ultrasonic energy greatly increased the rate of precipitation of latex on asbestos.[31]

A patent was granted on the use of a mixture of acrylic fiber and long chrysotile asbestos in the manufacture of a fireproof cloth.[32]

A process was patented for forming friction sheet material composed of crocidolite asbestos cotton linters, diatomite, and latex.[33]

A method was patented for preparing insulating boards or sheets from a mixture of 4T to 7K asbestos fiber with other materials.[34]

The use of amosite asbestos fiber in a sag-resistant felted mineral fiberboard containing mainly slag wool was patented.[35]

A method was patented for forming a high quality inert fabric for use in the filtration of hot or cold industrial gases. The fabric is strong, fireproof, chemically inert, and will filter fine solid particles out of gases.[36]

A patent was issued for the use of asbestos as a friction material in the manufacture of railroad composition brake blocks.[37]

A process for protecting metal surfaces was patented. Short fiber asbestos is sprayed into molten zinc coating, and the composite fiber-metal coating is dried.[38]

A method was patented for the use of asbestos in the preparation of felted asbestos paper or sheeting.[39]

A patent was issued on the use of asbestos fiber and a solid lubricant in the manufacture of stuffing box packings.[40]

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[29] Barrable, V. E., A. Bennett, and A. F. Jerome. Use of Crocidolite Asbestos in Reinforced Plastics. Industrial & Engineering Chemistry, v. 2, September 1963, pp. 186–189.

[30] Chemical Age (London). First Asbestos Reinforced Thermoplastic Laminate. V. 91, No. 2346, June 1964, p. 1014.

[31] Martinez, E. Effect of Ultrasonic Energy on Chrysotile Asbestos. Transactions of the Society of Engineers, v. 226, No. 4, December 1963, pp. 388–390.

[32] Crawley, W. P. (assigned to The Carborundum Co.). Heat Resistant Fibrous Products and Method of Making the Same. U.S. Pat. 3,125,404, Mar. 17, 1964.

[33] Schultz. H. W. (assigned to General Motors Corp.). Clutch Plate Facing. U.S. Pat. 3,141,814, July 21, 1964.

[34] Owens, W. G., and C. Haines, Jr. (assigned to Armstrong Cork Co.). Low-Density, Heat-Insulating Material. U.S. Pat. 3,147,177, Sept. 1, 1964.

[35] Cadotta, J. E. (assigned to Wood Conversion Co.). Production of Sag-Resistant Mineral Fiberboard. U.S. Pat. 3,146,156, Aug. 25, 1964.

[36] Gouzene, P. (assigned to Compagnie de Saint-Gobain, France). Filter Fabric and Method of Making It. U.S. Pat. 3,150,033, Sept. 22, 1964.

[37] de Gaugues, C. L. E., Jr. (assigned to Johns-Manville Corp.). U.S. Pat. 3,152,099, Oct. 6, 1964.

[38] Schendler, P. B. (assigned to Armco Steep Corp.). Process for Producing Protected Metal Surfaces. U.S. Pat. 3,155,530, Nov. 3, 1964.

[39] Morgan, R. W. (assigned to The Dow Chemical Co., Midland, Mich.). Method for Preparation of Asbestos Papers and Sheeting. U.S. Pat. 3,153,610, Nov. 20, 1964.

[40] Radke, R. Method for the Manufacture of Stuffing Box Packing. U.S. Pat. 3,157,983, Nov. 24, 1964.

A method was patented for weaving an improved filter bag fabric from spinning grade asbestos fiber and dacron or other polyester fiber.[41]

An air washer for removing dirt and grit from newly opened asbestos fiber was patented. The fiber is advanced by means of a screw conveyor through slots in the conveyor housing, with a series of sharp blasts of high-velocity air. Dust and fine fiber is carried to a separating chamber, and the main fiber product is discharged at the end of the conveyor.[42]

A method was patented for the production of pipes, paper, and sheets from an aqueous suspension of asbestos fiber and portland cement.[43]

A design for an improved apparatus was patented for producing sheets which show uniform high strength in all directions from an aqueous suspension of asbestos and portland cement.[44]

British patents covered a method for lining the heads of foundry molds with a composition of asbestos fiber and other materials,[45] for defiberizing asbestos fiber bundles which are to be used in the manufacture of asbestos-cement products,[46] for the use of asbestos in making preformed insulation shapes for insulating pipes, [47] and preventing brittleness in sheets made from an aqueous slurry of asbestos fiber and portland cement.[48]

An improved method was patented for forming and curing friction materials comprising 7D to 4T chrysotile asbestos fibers.[49]

A method was patented for the use of asbestos floats in the production of a gasket forming material.[50]

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[41] Barnet, I. (assigned to Johns-Manville Corp., New York). Filter Bag Fabric. U.S. Pat. 3,159,187, Dec. 1, 1964.

[42] Donovan, R. A. Air Washer for Asbestos Fiber. U.S. Pat. 3,163,595, Dec. 29, 1964.

[43] Schneider, R. A. (assigned to Certain-teed Products Corp.). Asbestos Cement Water-Laid Products Characterized by Equal Longitudinal to Transverse Strength Ratio. U.S. Pat. 3,120,465, Feb. 4, 1964.

[44] Amanzio, A. Apparatus for Producing Fiber Reinforced Cementitious Structure. U.S. Pat. 3,121,659, Feb. 18, 1964.

[45] Cherry, G. J. N. (assigned to Foseco Trading A. G.). British Pat. 952,786, Mar. 18, 1964.

[46] Bacher, J. P. (assigned to F. L. Smidth & Co., A/S.). British Pat. 953,596, Mar. 25, 1964.

[47] Jensen, H. (assigned to Park Sectional Insulating Co. Lt.). British Pat. 956,511, Apr. 29, 1964.

[48] Patterson, N. F. (assigned to Monsanto Chemicals Ltd.). British Pat. 958,286, May 21, 1964.

[49] Cofek, H. J. (assigned to Raybestos-Manhattan, Inc.). Canadian Pat. 693,430, Sept. 1, 1964.

[50] Rucker, H. L. (assigned to Johns-Manville Corp.). Canadian Pat. 694,291, Sept. 15, 1964.

Barite

By John W. Cole[1]

❖

BARITE production, consumption, and imports reflected an increase of 4 percent in the number of wells drilled for oil and gas. Production increased 2 percent, imports increased 4 percent, and consumption increased 4 percent.

TABLE 1.—Salient barite and barium-chemical statistics

(Thousand short tons and thousand dollars)

	1955-59 (average)	1960	1961	1962	1963	1964
United States:						
Primary:						
Mine or plant production	1,025	771	731	887	803	817
Sold or used by producers	1,012	714	797	860	824	830
Value	$11,002	$8,574	$9,300	$9,820	[r] 9,402	$9,796
Imports for consumption	589	642	608	737	578	600
Value	$4,041	$5,006	$5,185	$6,009	$4,637	$4,796
Consumption [1]	1,552	1,190	1,391	[r] 1,211	[r] 1,230	1,277
Ground and crushed sold by producers	1,288	977	1,036	1,023	1,030	1,077
Value	$34,674	$24,219	$25,182	$24,285	$25,517	$26,948
Barium chemicals sold by producers	95	99	97	104	[r] 109	117
Value	$12,988	$14,152	$13,770	$14,656	[r] $15,837	$17,101
World: Production	3,090	3,130	3,160	3,420	3,190	3,370

[r] Revised.
[1] Includes some witherite.

DOMESTIC PRODUCTION

Missouri continued, for the fourth consecutive year, to be the largest producer of barite, with Arkansas the second largest producer.

Stocks of primary barite at domestic mines decreased 14 percent, to 116,000 tons. Yearend inventories of crushed and ground barite totaled 29,391 tons—about the same as at the beginning of the year. Production and sales each were about 5 percent higher than in 1963.

Production of barium chemicals increased 8 percent which was the greatest increase in the past 4 years of rising production.

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[1] Commodity specialist, Division of Minerals.

TABLE 2.—Domestic barite sold or used by producers in the United States, by States

(Thousand short tons and thousand dollars)

State	Quantity	Value	Quantity	Value	Quantity	Value
	1955–59 (average)		1960		1961	
Arkansas	389	$3,463	278	$2,578	278	$2,630
California	(1)	(1)	16	181	21 107	295 2,046
Georgia	136	2,370	119	2,347	13	253
South Carolina						
Tennessee						
Kentucky	(1)	(1)	(1)	(1)	(1)	(1)
Missouri	312	3,799	181	2,588	227	3,052
Nevada	110	704	86	591	130	863
Other States [2]	65	666	34	289	21	161
Total	1,012	11,002	714	8,574	797	9,300
	1962		1963		1964	
Arkansas	259	$2,232	236	$2,161	233	$2,202
California	7	133	5	[r]31	6	45
Georgia	109	1,987	117	2,013	109	2,022
Kentucky	(1)	(1)	6	85	6	96
Missouri	304	3,994	287	3,680	267	3,451
Nevada	138	954	120	760	149	1,261
South Carolina	16	327	(1)	(1)	(1)	(1)
Tennessee			24	404	39	519
Other States [2]	27	193	29	268	20	200
Total	860	9,820	824	[r]9,402	830	9,796

[r] Revised.

[1] Included with "Other States" to avoid disclosing individual company confidential data.

[2] Arizona (1955) only, Idaho (1960–64), Kentucky (1959–62), Montana (1959–64), New Mexico (1959–64), South Carolina (1963–64), and Texas (1961–64).

CONSUMPTION AND USES

The quantity of ground barite used in the paint industry increased 70 percent over 1963. This use has increased from 2 percent of the total ground and crushed barite sold by producers in 1962 to 6 percent in 1964. The percent of the total quantity used by the well-drilling industry continued to decline from 94 percent in 1960 to 87 percent in 1964.

TABLE 3.—Ground and crushed barite produced and sold by producers in the United States

(Thousand short tons and thousand dollars)

Year	Number of plants	Production (quantity)	Sales		Year	Number of plants	Production (quantity)	Sales	
			Quantity	Value				Quantity	Value
1955–59 (average)	32	1,327	1,288	$34,674	1962	35	1,012	1,023	$24,285
1960	36	973	977	24,219	1963	34	1,027	1,030	25,517
1961	35	1,101	1,036	25,182	1964	33	1,079	1,077	26,948

TABLE 4.—Crude barite (domestic and imported) used in the manufacture of ground barite and barium chemicals in the United States[1]

(Thousand short tons)

Year	In manufacture of —		Total	Year	In manufacture of —		Total
	Ground barite[2]	Barium chemicals and lithopone			Ground barite[2]	Barium chemicals and lithopone	
1955–59 (average)	1,376	176	1,552	1962	1,043	[r]168	[r]1,211
1960	1,005	185	1,190	1963	1,048	[r]182	[r]1,230
1961	1,224	167	1,391	1964	1,103	174	1,277

[r] Revised.

[1] Includes some witherite in the manufacture of barium chemicals.

[2] Includes some crushed barite.

TABLE 5.—Ground and crushed barite sold by producers, by consuming industries

Industry	Short tons	Percent of total	Short tons	Percent of total	Short tons	Percent of total
	1955–59 average		1960		1961	
Well drilling	1,217,310	94	920,283	94	941,539	91
Glass	22,210	2	15,012	1	30,713	3
Paint	18,820	1	18,273	2	16,128	2
Rubber	21,436	2	17,082	2	24,007	2
Undistributed	8,039	1	6,180	1	23,395	2
Total	1,287,815	100	976,830	100	1,035,782	100
	1962		1963		1964	
Well drilling	934,007	91	907,134	89	930,965	87
Glass	39,017	4	56,362	5	56,866	5
Paint	19,786	2	34,611	3	58,396	6
Rubber	26,235	3	28,479	3	26,675	2
Undistributed	4,045		3,121		3,787	
Total	1,023,090	100	1,029,707	100	1,076,689	100

TABLE 6.—Barium chemicals produced and used or sold by producers in the United States

(Short tons)

Chemical and year	Number of plants	Produced	Used[1] by producers[2] in other barium chemicals	Sold by producers[3]	
				Quantity	Value
Black ash:[4]					
1955–59 (average)	9	115,358	111,794	2,737	$236,993
1960	9	116,995	113,466	3,136	298,741
1961	8	105,117	102,591	2,363	228,358
1962	r 10	r 107,418	r 105,114	3,393	365,904
1963	r 8	r 112,953	r 102,945	3,374	322,941
1964	9	114,421	110,676	3,605	344,295
Carbonate (synthetic):					
1955–59 (average)	6	74,546	29,117	45,836	4,598,600
1960	6	77,690	29,392	46,128	5,010,514
1961	7	78,665	28,599	47,401	5,119,826
1962	r 7	r 79,313	27,683	49,484	5,415,751
1963	r 7	r 78,411	25,688	r 52,026	r 5,685,281
1964	7	81,018	28,088	53,897	6,021,728
Chloride (100 percent $BaCl_2$):					
1955–59 (average)	3	8,348	50	8,054	1,252,631
1960	3	8,754	---	9,401	1,535,188
1961	3	10,891	---	10,290	1,697,606
1962	r 5	r 10,888	---	10,276	1,703,123
1963	r 4	r 11,100	---	r 11,299	r 1,842,105
1964	5	11,425	---	11,590	1,926,885
Hydroxide:					
1955–59 (average)	5	13,876	85	13,894	2,463,132
1960	5	17,579	---	14,971	2,336,402
1961	4	13,715	---	13,873	2,167,245
1962	4	16,328	---	16,925	2,745,135
1963	4	18,746	---	18,436	3,018,482
1964	5	23,384	W	23,313	3,688,060
Other barium chemicals:[5]					
1955–59 (average)	---	32,210	6,748	24,621	4,436,941
1960	---	30,690	W	25,464	4,971,000
1961	---	27,878	W	23,452	4,557,193
1962	---	27,850	W	23,864	4,425,798
1963	---	26,555	W	23,462	4,967,844
1964	(6)	28,365	W	24,598	5,120,053
Total:[7]					
1955–59 (average)	---	---	---	95,142	12,988,297
1960	14	---	---	99,100	14,151,845
1961	14	---	---	97,379	13,770,228
1962	r 15	---	---	103,942	14,655,711
1963	r 14	---	---	r 108,597	r 15,836,653
1964	14	---	---	117,003	17,101,021

Revised. W Withheld to avoid disclosing individual company confidential data.

[1] Includes also purchased material.

[2] Of any barium chemical.

[3] Exclusive of purchased material and exclusive of sales by one producer to another.

[4] Black-ash data include lithopone plants.

[5] Includes barium acetate, nitrate, oxide, peroxide, sulfate, and other compounds for which separate data may not be revealed.

[6] Barium acetate, 1 plant; nitrate, 3; oxide, 1; peroxide, 2; and sulfate (synthetic) 5.

[7] A plant producing more than 1 product is counted only once in arriving at total.

PRICES

Prices of crude and ground domestic or imported barite were unchanged during the year.

TABLE 7.—Price quotations for barite, crude and ground, in 1964

(Per short ton)

	1964
Chemical grade:	
Hand picked, 95 percent $BaSO_4$, 1 percent Fe	$18.50
Flotation or magnetic separation; 96–97½ percent $BaSO_4$, 0.3–0.7 percent Fe (add $3 for 100-lb. bags)	19 to 23.50
Water ground; 99½ percent $BaSO_4$, 325 mesh, 50-lb. bags	45 to 49
Drilling mud grade:	
83–93 percent $BaSO_4$, 3–12 percent Fe specific gravity 4.20–4.30	
Crude, bulk	12 to 16
Some restricted sales	11.50
Ground	26.75
Imported—4.20–4.30 specific gravity, bulk, c.i.f. gulf ports	11 to 14

Source: E&MJ Metal and Mineral Markets.

TABLE 8.—Price quotations for barium chemicals in 1964

(Per short ton, except as noted)

	1964
Barium carbonate, precipitated, bags, carlots, works	$111.50
Barium chlorate, drums, works per pound	.32 to .41
Barium chloride, anhydrous, bags, carlots, works	176.00
Barium dioxide (peroxide), drums, freight equalized per pound	.30
Barium hydrate, crystalline, bags, carlots, truckloads, delivered	224.00
Barium monohydrate, 99 percent, bags, carlots, delivered, 100 pounds	12.00
Barium nitrate, barrels, carlots, truckloads, delivered per pound	.16
Less carlots, less truckloads, delivered do	.17
Barium oxide, ground, drums, carlots, truckloads, freight, delivered	288.00
Blanc fixe, direct process, bags, carlots, works	160.00

Source: Oil, Paint and Drug Reporter.

FOREIGN TRADE

Imports of crude barite increased slightly above the quantity imported during 1963. The average declared per ton value of crude barite imports was as follows: Mexico, $6.47; Canada, $8.49; Peru, $9.64; Greece, $7.59; Morocco, $9.52; Yugoslavia, $7.82; Ireland, $7.56; Italy, $9.08; and Spain, $8.42.

The quantity of barium chemicals imported increased 12 percent primarily because of a 44-percent increase in blanc fixe.

Witherite was imported from the United Kingdom.

TABLE 9.—U.S. imports for consumption of barite, by countries

	1963		1964	
	Short tons	Value	Short tons	Value
Crude barite:				
North America:				
Canada	150,881	$1,187,460	141,845	$1,204,669
Mexico	159,964	1,081,821	188,635	1,219,540
Total	310,845	2,269,281	330,480	2,424,209
South America:				
Brazil	13,070	94,856	---	---
Peru	91,295	903,158	117,937	1,137,265
Total	104,365	998,014	117,937	1,137,265
Europe:				
Greece	48,081	362,454	24,512	186,031
Ireland	10,483	70,200	63,541	480,528
Italy	---	---	7,648	69,456
Spain	18,852	183,829	8,572	72,155
Yugoslavia	33,688	323,571	14,080	110,117
Total	111,104	940,054	118,353	918,287
Africa: Morocco	51,784	430,028	33,179	315,772
Grand total	578,098	4,637,377	599,949	4,795,533
Ground barite:				
North America:				
Canada	13	375	997	37,967
Mexico	243	3,890	---	---
Total	256	4,265	997	37,967
Europe:				
Germany, West	23	896	64	3,295
Spain	17	450	---	---
Total	40	1,346	64	3,295
Grand total	296	5,611	1,061	41,262

Source: Bureau of the Census.

TABLE 10.—U.S. imports for consumption of barium chemicals

Year	Short tons	Value	Short tons	Value	Short tons	Value	Short tons	Value
	Lithopone		Blanc fixe (precipitated barium sulfate)		Barium chloride		Barium hydroxide	
1955–59 (average)	74	$10,094	1,341	$107,512	1,333	$113,377	109	$17,080
1960	62	7,973	1,629	124,093	1,004	91,843	39	16,172
1961	74	8,843	1,378	122,174	1,019	93,105	11	1,880
1962	98	12,538	1,724	152,267	1,150	107,214	11	1,680
1963	159	21,360	1,602	157,332	1,152	103,890	---	---
1964	175	19,043	2,314	217,595	1,133	101,018	6	945

Year	Short tons	Value	Short tons	Value	Short tons	Value
	Barium nitrate		Barium carbonate, precipitated		Other barium compounds	
1955–59 (average)	553	$84,741	1,440	$98,444	227	$58 105
1960	736	106,818	1,406	104,674	172	132,294
1961	807	128,120	1,190	86,123	160	111,427
1962	807	125,253	1,501	112,406	126	95,931
1963	948	145,341	838	58,302	107	78,286
1964	601	90,176	1,040	71,367	96	47,733

Source: Bureau of the Census.

TABLE 11.—U.S. imports for consumption of crude, unground, and crushed or ground witherite[1]

Year	Crude unground		Crushed or ground	
	Short tons	Value	Short tons	Value
1962	1,431	$58,766	71	$4,726
1963	2,690	113,813	90	5,956
1964	2,407	97,546	25	1,708

[1] Class established June 1, 1956; no transactions; 1957, 8 tons ($533); 1958, 202 tons ($15,610); 1959, less than ½ unit ($478).

Source: Bureau of the Census.

TABLE 12.—U.S. exports of lithopone

Year	Short tons	Value
1962	350	$68,317
1963	839	135,874
1964	1,184	191,774

Source: Bureau of the Census.

WORLD REVIEW

World production increased 6 percent over that of 1963. Increases in production in Mexico and Ireland were significant.

TABLE 13.—World production of barite, by countries [1] [2]

(Short tons)

Country [1]	1955–59 (average)	1960	1961	1962	1963	1964 [p]
North America:						
Canada	247,461	154,292	191,403	226,600	173,503	172,415
Cuba (exports)	6,946	---	---	---	---	---
Mexico	310,955	298,458	274,153	350,684	283,246	359,372
United States	1,024,812	771,318	731,381	886,964	803,106	816,706
Total	1,590,174	1,224,068	1,196,937	1,464,248	1,259,855	1,348,493
South America:						
Argentina	21,090	26,987	31,476	13,819	15,558	[3] 15,558
Brazil	40,027	44,464	68,834	60,241	37,601	[3] 37,601
Chile	1,059	1,991	1,551	1,156	1,123	1,287
Colombia	9,461	8,000	11,272	8,800	11,600	[3] 11,600
Peru	67,980	120,800	122,538	126,271	137,600	145,934
Total	139,617	202,242	235,671	210,287	203,482	211,980
Europe:						
Austria (marketable)	4,088	4,829	2,716	1,192	2,395	1,256
France	89,035	116,860	95,007	92,570	82,080	[3] 82,080
Germany, West (marketable)	468,751	549,134	518,951	512,230	466,419	487,884
Greece	101,297	112,203	85,000	78,406	95,000	75,000
Ireland	8,133	11,704	4,659	22	10,192	68,629
Italy	119,873	157,925	155,999	134,388	117,505	93,404
Poland	12,192	[e] 12,400	41,161	49,841	50,400	[3] 50,400
Portugal	1,334	4,310	2,285	1,489	1,828	383
Spain	19,644	28,596	37,449	42,923	53,312	[3] 53,312
U.S.S.R. [e]	120,000	140,000	165,000	200,000	220,000	220,000
United Kingdom [4]	79,880	67,431	91,677	84,754	61,066	64,000
Yugoslavia	113,441	120,691	114,872	114,379	115,176	126,694
Total [e] [1]	1,170,000	1,360,000	1,350,000	1,350,000	1,310,000	1,360,000
Asia:						
Burma	[5] 1,014	1,792	2,248	4,462	---	---
China [e]	40,000	65,000	90,000	90,000	100,000	110,000
India	12,509	14,976	17,325	36,004	41,129	50,594
Iran [6]	[5] 1,911	14,330	20,900	16,500	[e] 16,500	[e] 16,500
Japan	21,261	25,184	32,243	42,016	41,360	42,010
Korea:						
North [e]	[7] 16,500	45,000	60,000	65,000	75,000	75,000
South	333	220	770	1,014	3,040	[e] 3,000
Pakistan	455	709	489	3,164	5,330	13,325
Philippines	[8] 2,846	6,198	2,109	459	1,008	1,627
Turkey	[9] 2,139	1,653	---	2,094	1,081	6,669
Total [e] [1]	99,000	175,000	226,000	261,000	284,000	319,000
Africa:						
Algeria	42,555	61,564	33,883	13,417	7,518	[3] 7,518
Morocco	32,740	92,945	90,591	98,980	104,228	99,036
Rhodesia (formerly Southern)	55	---	---	---	1,953	1,561
South Africa, Republic of	2,610	1,878	1,962	1,873	2,704	2,835
Swaziland	451	200	454	68	93	17
United Arab Republic (Egypt)	950	2,998	1,734	1,355	4,545	5,017
Total	79,361	159,585	128,624	115,693	121,041	115,984
Oceania: Australia	7,855	12,787	21,523	14,038	9,206	[e] 12,700
World total (estimate) [1] [2]	3,090,000	3,130,000	3,160,000	3,420,000	3,190,000	3,370,000

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[e] Estimate. [p] Preliminary.

[1] Barite is produced in Bulgaria, Czechoslovakia, and East Germany, but data on production are not available. Estimates by author of chapter included in total, with the exception of Bulgaria.

[2] This table incorporates some revisions. Data do not add exactly to totals shown because of rounding where estimated figures are included in the detail.

[3] 1963 data.

[4] Includes witherite.

[5] Average annual production 1958–59.

[6] Year ended March 20 of year following that stated.

[7] Data for 1959 only.

[8] Average annual production 1956–59.

[9] Average annual production 1957–59.

Czechoslovakia.—The Erith Works of G.E.C. (Engineering) Ltd. received an order from Strojexport, Czechoslovakia for drying, grinding, and classifying equipment for handling bleached barite to give a product 99.9 percent through a 325 mesh Tyler screen.[2]

Jordan.—Discovery of barite deposits east of Bethlehem was reported.[3] Although no estimate of quantity and grade was given, the major seam was stated to be 13 meters thick.

United Kingdom.—A new company, Barium Chemicals, Ltd., was organized to absorb the barium operations of Imperial Smelting Corporation, Ltd., Widnes, and Laporte Chemicals, Ltd., Luton. Fifty percent of the new company is owned by each of the predecessor companies.

The chairman of McKechnie Brothers, Ltd. announced that a new barium chloride plant will be built at the Widnes works.

Yugoslavia.—A translation of an article describing barite deposits of Bosnia and Herzegovina was published.[4]

TECHNOLOGY

The geology and deposits of barite in the State of Washington were described.[5] Geology, specific gravity of ore, and estimated reserves were tabulated for 27 deposits in Stevens County and 1 in Pend Oreille County. The estimated reserve for individual deposits ranged up to 200,000 tons, but usually was less than 20,000 tons.

Geology and deposits of barite-fluorspar-galena ores of the Hansonburg mining district, Socorro County, N. Mex., were described in detail.[6]

Based on the results of a series of bench-scale flotation tests on barite-fluorite ore from Arizona,[7] a small scale continuous test demonstrated the feasibility of producing both acid-grade fluorite and barite suitable for use in oil-well drilling mud. Sodium fluoride, calcium lignin sulfonate, and 42-06 fatty acid were used in floating the fluorite, and sodium cetyl sulfate was used to float the barite.

Continuous flotation tests on a scale of about 150 pounds of ore per hour were conducted on a ferruginous barite-fluorspar ore from Tennessee.[8] Recoveries of 91.2 percent of the fluorspar in a concentrate that assayed 98.3 percent calcium fluoride (CaF_2) and 85.2 percent of the barite in a concentrate that assays 91.2 percent barium sulfate ($BaSO_4$) were achieved. The lignin sulfonate-sodium fluoride-fatty acid method was used to float the fluorspar, and petroleum sulfonate was used to float the barite from the fluorspar flotation tailing.

An article was published giving interpretation of a study of mineral zoning in the Illinois-Kentucky fluorspar mining district.[9] Vertical and lateral grading of fluorspar into barite were interpreted to indicate possible centers of mineralization.

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[2] Mine and Quarry Engineering (London). V. 30, No. 3, March 1964, p. 120.

[3] Bureau of Mines. Mineral Trade Notes. V. 58, No. 4, April 1964, p. 5.

[4] Ramovic, Mehmed. Barite Deposits in Bosnia and Herzegovina. (Yugoslavia, 1956). Tech. Trans. Office of Tech. Services, U.S. Dept. of Commerce, 1963, 20.pp

[5] Moen, Wayne S. Barite in Washington. Washington Dept. of Conservation, Division of Mines and Geology, Bull. 51, 1964, 112 pp.

[6] Williams, Frank E., P. V. Fillo, and P. A. Bloom. Barite Deposits of New Mexico. State Bureau of Mines and Mineral Resources, Socorro, N. Mex., Circ. 76, 1964, 45 pp.

[7] Bloom, P. A., W. A. McKinney, and L. G. Evans. Flotation Concentration of a Complex Barite-Fluorspar Ore. BuMines, Rept. of Inv. 6213, 1963, 16 pp.

[8] Eddy, W. H., and J. S. Browning. Selective Flotation of a Barite-Fluorspar Ore from Tennessee. BuMines, Rept. of Inv. 6491, 1964, 8 pp.

[9] Brecke, E. A. Barite Zoning in the Illinois-Kentucky Fluorspar District. Econ. Geol., v. 59, No. 2, March-April 1964.

Barium concentrations of 500 to 10,000 parts per million in soil and rock may be determined by a comparatively simple field test.[10] It was used in testing about 3,500 samples. Check analyses of 220 of the samples by the spectrographic method showed that 83 percent were in the same concentration class. The method is based on the reactions of barium with sulfate to form barium sulfate, which imparts a turbidity to an aqueous solution proportional to the barium content.

In the barium chemical field a British patent [11] was issued on a method of preparing barium hydroxide monohydrate. The method was patented in the United States in 1963.[12] A 50 to 66 percent (by weight) aqueous barium hydroxide ($Ba(OH)_2$) solution is transferred as a film not more than 0.025 inch in thickness to a dispersing apparatus, preferably a splash pan, and the latter is heated at 225° to 275° F until dryed flakes are formed. In a cited example, the product contained 97.6 percent barium hydroxide monohydrate [$Ba(OH)_2 \cdot H_2O$].

Methods of production and specifications of barium titanate ceramic disks for capacitors and other dielectric purposes were summarized.[13] Barium carbonate and titanium dioxide are mixed by wet milling, dried, micropulverized, tempered with about 8 percent water, mixed, and granulated by forcing through a 20-mesh screen. Disks are formed from the granulated material by a pressure of about 10,000 pounds per square inch. Common size of the disks is 0.25 inch in thickness and 1 inch in diameter. The disks are fired at temperatures of 2,400° to 2,500° F.

A patent was issued[14] covering the preparation of barium ferrite, ($BaO \cdot 6Fe_2O_3$). Barium carbonate is precipitated from an aqueous solution of barium hydroxide onto ferric oxide particles. The resulting material is calcined to produce $BaO \cdot 6Fe_2O_3$.

A method was proposed for removing sulfate ions from liquids that have been used as a solvent in spinning filaments of a crylonitrile and copolymers; this method contacts the liquid with solid, pulverulent barium carbonate and then separates the solid from the liquid.[15]

Development of the most powerful fuel cell yet designed was announced by the M. W. Kellog Company.[16] This cell uses barium as fuel with oxygen or chlorine as an oxidizer. Net energy density of the barium cell was calculated to have a cell volume of 11.5 to 14.5 kilowatt-hours per cubic foot after 1 hour of operation compared with 4 kilowatt-hours per cubic foot for silver-zinc batteries. The barium fuel is not regenerable.

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[10] Brobst, Donald A., and F. N. Ward. A Turbidimetric Test for Barium and Its Geologic Application in Arkansas. Econ. Geol., v. 59, No. 8, December 1964, p. 1620.

[11] FMC Corporation. Barium Hydroxide Monohydrate. British Pat. 959,135, Sept. 4, 1964.

[12] Drake, Harold J. Barite. BuMines Minerals Yearbook, 1963, v. 1, 1964, p. 276.

[13] Ceramic Industry. January 1964, p. 78.

[14] Erickson, Robert H., and Sol Boyk (assigned to General Magnetic Corporation). Method for Making Barium Ferrite Magnets. U.S. Pat. 3,155,623, Sept. 3, 1964.

[15] Schmidt, W. C., and A. T. Bucknall (assigned to Courtaulds Limited, London). Purification of a Spent Thiocyanate Solvent Solution Containing Sulfate Ions as Impurities. U.S. Pat. 3,123,437, Mar. 3, 1964.

[16] Chemical Week. Barium Boosts Fuel Cell Punch. V. 95, No. 16, Oct. 17, 1964, pp. 38–40.

Bauxite

By Lloyd R. Williams [1]

⁂

WORLD production of bauxite reached a new high, 33 million tons, 10 percent more than in 1963. Over 51 percent of the world production was in the Western Hemisphere. Jamaica was the leading producer, followed by Surinam and British Guiana. Bauxite continued to be the main source of alumina required for the production of aluminum metal.

Production of bauxite in the United States increased 5 percent and was equivalent to 13 percent of the domestic supply of new bauxite. A record 5.6 million short tons of alumina and aluminum oxide products was produced from bauxite. Aluminum production accounted for 83 percent of the bauxite consumed. (Aluminum metal is discussed in the "Aluminum" chapter of this volume.)

TABLE 1.—Salient bauxite statistics

(Thousand long tons and thousand dollars)

	1955-59 (average)	1960	1961	1962	1963	1964
United States:						
Production, crude ore (dry equivalent)	1,592	1,998	1,228	1,369	1,525	1,601
Value	$14,612	$21,107	$13,937	$15,609	$17,234	$17,875
Imports for consumption [1]	6,743	8,739	9,206	10,575	[r] 9,212	10,180
Exports (as shipped)	24	29	151	259	203	294
Consumption (dry equivalent)	7,605	8,883	8,621	10,577	11,318	12,546
World: Production	20,920	[r] 27,205	[r] 28,895	[r] 30,895	[r] 30,220	33,145

[r] Revised.

[1] Includes bauxite imported for Government account. Import figures for Jamaican, Haitian, and Dominican Republic bauxite included were adjusted by Bureau of Mines to dry equivalent. Other imports, which are virtually all dried, are on an as-shipped basis.

Legislation and Government Programs.—No withdrawls were made from the Government strategic or nonstrategic stockpiles. Jamacian, Surinam, and refractory types of bauxite remained on the group I list of strategic materials for the national stockpile.

During the year, 317,000 long dry tons of Jamaican-type ore was acquired by barter, bringing the total Government inventories to 8,347,000 tons of Jamaican-type ore.

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[1] Commodity specialist, Division of Minerals.

TABLE 2.—Government inventories as of December 31, 1964

	Alumina (short dry tons)		Bauxite (long tons)		
	Crude fused	Abrasive grain	Metal grade, dried		Refractory grade, calcined
			Jamaican type	Surinam type	
Objective	160,000		5,000,000	5,300,000	173,000
Government inventories:					
National (strategic) stockpile	200,000		880,000	4,963,000	299,000
DPA inventories			1,370,000		
CCC and supplemental stockpile	178,000	51,000	6,097,000	2,927,000	
Total	378,000	51,000	8,347,000	7,890,000	299,000

DOMESTIC PRODUCTION

Output of crude bauxite in the United States increased 5 percent, while shipments to consumers from mines and processing plants increased 3 percent.

Arkansas produced 98 percent of the total U.S. output. The two leading producers in Arkansas were Aluminum Company of America (Alcoa) and Reynolds Metals Co., and each shipped crude ore to its own alumina plant. Calcined bauxite was produced by American Cyanamid Co. and Stauffer Chemical Co. Activitated bauxite was produced by Porocel Corp. and Stauffer Chemical Co. Norton Co. did not operate its mine or plant in Saline County, and Campbell Bauxite Co. discontinued operations in Pulaski County.

Harbison-Walker Refractories Co., R. E. Wilson Mining Co., and Wilson-Snead Mining Co. operated bauxite mines in Barbour and Henry Counties, Ala., and American Cyanamid Co. mined in Floyd and Sumter Counties, Ga. Together they produced 39,000 long dry tons of ore, a 17-percent decrease from 1963 output. Crude ore was shipped to consumers by the Wilson-Snead Mining Co. and the American Cyanamid Co. American Cyanamid Co. and R. E. Wilson Mining Co. processed their crude ore and produced dried bauxite, and Harbison-Walker Refractories Co. produced calcined bauxite.

With the change by the steel industries to basic brick in open hearth furnace roofs, the demand for silica brick decreased, seriously affecting the operation of the General Refractories Co. Warren, Ohio, plant, a major producer of silica brick. Facilities at the Warren plant were converted to produce silica brick, semisilica brick, and high-alumina brick.[2]

Reynolds Aluminum Co., planned to increase alumina capacity at Corpus Christi, Tex., from 2,500 to 3,000 tons per day, with arrangements to use a greater variety of bauxite. This involves installation of a fifth digester train, a lime hydrator, grinding mills, a boiler, and a turbo generator, and modernization of existing equipment.

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[2] Iron & Steel Engineer. General Refractories Co. Modernizes Warren Plant. V. 41, No. 3, March 1964, p. 162.

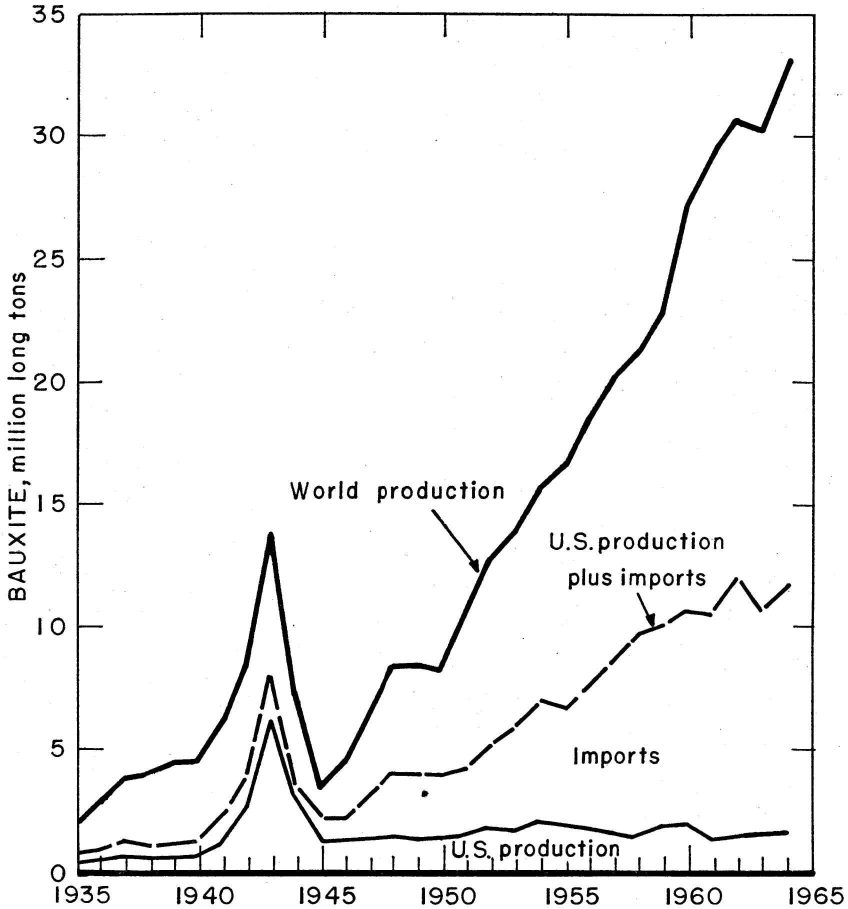

FIGURE 1.—U.S. supply and world production of bauxite.

Reynolds also planned to increase production of alumina chemicals at its Hurricane Creek, Ark., plant by modernizing and conversion.

Kaiser Refractories Division, Kaiser Aluminum & Chemical Corp., Oakland, Calif., announced production of three grades of a high-alumina phosphate-bond brick containing 70, 80, or 90 percent aluminum, depending on grade.

The Kaiser Chemical Division planned to install a new hydrogen fluoride generator at the Gramercy, La., plant and expand other facilities to increase production of aluminum fluoride by 50 percent.

Both Baton Rouge and Gramercy alumina plants were scheduled for improvement.

Armour Pharmaceutical Co. completed facilities for production of aluminum hydroxide gels at Kankakee, Ill.

Allis-Chalmers Manufacturing Co. of Milwaukee, Wis., started producing 98 percent aluminum carbide on a commercial scale in the form of a fine powder for use as a catalyst and deoxidizing agent.

TABLE 3.—Mine production of bauxite and shipments from mines and processing plants to consumers in the United States

(Thousand long tons and thousand dollars)

State and year	Mine production			Shipments from mines and processing plants to consumers		
	Crude	Dry equivalent	Value [1]	As shipped	Dry equivalent	Value [1]
Alabama and Georgia:						
1955–59 (average)	83	65	$583	68	63	$684
1960	82	66	638	49	51	577
1961	60	49	475	40	43	498
1962	120	99	1,003	50	53	609
1963	60	47	533	54	62	747
1964	51	39	444	57	57	809
Arkansas:						
1955–59 (average)	1,820	1,527	14,029	1,835	1,571	15,660
1960	2,327	1,932	20,469	1,876	1,603	18,982
1961	1,419	1,179	13,462	1,244	1,080	13,220
1962	1,523	1,270	14,606	1,715	1,481	17,535
1963	1,771	1,478	16,701	1,725	1,483	17,543
1964	1,864	1,562	17,431	1,773	1,531	17,859
Total United States:						
1955–59 (average)	1,903	1,592	14,612	1,903	1,634	16,344
1960	2,409	1,998	21,107	1,925	1,654	19,559
1961	1,479	1,228	13,937	1,284	1,123	13,718
1962	1,643	1,369	15,609	1,765	1,534	18,144
1963	1,831	1,525	17,234	1,779	1,545	18,290
1964	1,915	1,601	17,875	1,830	1,588	18,668

[1] Computed from selling prices and values assigned by producers and estimates of the Bureau of Mines.

TABLE 4.—Recovery of dried, calcined, and activated bauxite in the United States

(Long tons)

Year	Crude ore treated	Processed bauxite recovered			
		Dried	Calcined or activated	Total	
				As recovered	Dry equivalent
1955–59 (average)	195,358	107,200	31,741	138,941	153,253
1960	186,094	46,015	58,373	104,388	147,079
1961	153,321	30,202	55,242	85,444	124,992
1962	172,262	37,776	57,232	95,008	141,969
1963	170,641	35,727	61,853	97,570	164,072
1964	166,884	W	W	93,235	128,347

W Withheld to avoid disclosing individual company confidential data.

CONSUMPTION AND USES

Domestic consumption of bauxite increased 11 percent. Foreign sources supplied 86 percent of the total consumption. Jamaican-type ore (from Jamaica, Haiti, and the Dominican Republic) comprised 56 percent of the total consumption; Surinam-type ore (from Surinam and British Guiana) made up 30 percent. Domestic sources supplied the remainder.

Shipments of domestic ore (an index of the grade of ore consumed) containing less than 8 percent silica were 6 percent of the total, a decrease from the 8 percent shipped in 1963. The proportion of ore containing 8 to 15 percent silica increased from 53 to 63 percent, and the proportion of the ore containing more than 15 percent silica decreased to 31 percent, 8 percent less than in 1963.

The eight domestic alumina plants operated by the aluminum companies produced 5,493,000 short tons of calcined alumina and aluminum oxide products calculated on the basis of calcined equivalent. This was 10 percent more than in 1963. The gross weight of the calcined alumina and aluminum oxide products was 5,577,000 tons, of of which 5,279,000 tons was calcined alumina and 237,000 tons was trihydrate alumina. The remainder was activated or tabular alumina. Shipments of alumina and aluminum oxide products totaled 5,491,000 tons, of which 94 percent, or 5,182,000 tons, went to the aluminum industry. The remaining 309,000 tons was shipped as commercial trihydrate or as activated, calcined, or tabular alumina for use chiefly by the chemical, abrasive, ceramic, and refractory industries.

Calcined alumina consumed at the 22 aluminum reduction plants in the United States totaled 4,849,000 short tons, 13 percent more than in 1963. An average of 2.143 long dry tons of bauxite was required to

TABLE 5.—Bauxite consumed in the United States, by industries

(Long tons, dry equivalent)

Year and industry	Domestic	Percent	Foreign	Percent	Total	Percent
1963:						
Alumina	1,539,568	91.8	9,056,047	93.9	10,595,615	93.6
Abrasive [1]	--------	--------	230,045	2.4	230,045	2.0
Chemical	90,583	5.4	158,707	1.6	249,290	2.2
Refactory	26,259	1.6	152,381	1.6	178,640	1.6
Other	21,067	1.2	43,087	.5	64,154	.6
Total [1]	1,677,477	100.0	9,640,267	100.0	11,317,744	100.0
Percent	14.8	XX	85.2	XX	100.0	XX
1964:						
Alumina	1,576,145	91.3	10,193,109	94.2	11,769,254	93.8
Abrasive [1]	(2)	--------	240,469	2.2	240,469	1.9
Chemical	96,133	5.6	158,600	1.5	254,733	2.0
Refractory	31,174	1.8	187,909	1.7	219,083	1.8
Other	22,745	1.3	39,297	.4	62,042	.5
Total [1]	1,726,197	100.0	10,819,384	100.0	12,545,581	100.0
Percent	13.8	XX	86.2	XX	100.0	XX

XX Not applicable.

[1] Includes consumption by Canadian abrasives industry.

[2] Included with "Other" to avoid disclosing individual company confidential data.

TABLE 6.—Bauxite consumed in the United States in 1964, by grades

(Long tons, dry equivalent)

Grade	Domestic origin	Foreign origin	Total	Percent
Crude	1,599,531	409,660	2,009,191	16.0
Dried	24,937	10,012,077	10,037,014	80.0
Calcined	88,659	397,647	486,306	3.9
Activated	13,070	--------	13,070	.1
Total	1,726,197	10,819,384	12,545,581	100.0

produce 1 short ton of alumina, and an average of 1.901 short tons of alumina was required to produce 1 short ton of aluminum metal. The overall ratio was 4.074 long dry tons of bauxite to 1 short ton of aluminum.

A dense, high-purity, low-soda alumina ceramic was made available by Reynolds Metals Co. for uses ranging from spark plugs to missile nose cones.

TABLE 7.—Capacities of domestic alumina plants in operation and under construction

Company and plant	Capacity as of Dec. 31, 1964 (short tons per year)	
	Operating plants	Plants under construction
Aluminum Company of America:		
Mobile, Ala	985,500	
Bauxite, Ark	420,000	
Point Comfort, Tex	750,000	
Total	2,155,500	
Reynolds Metals Co.:		
Hurricane Creek, Ark	803,000	
La Quinta, Tex	876,000	220,000
Total	1,679,000	220,000
Kaiser Aluminum & Chemical Corp.:		
Baton Rouge, La	850,000	
Gramercy, La	430,000	
Total	1,280,000	
Ormet Corp.: Burnside, La	345,000	
Harvey Aluminum, Inc.: St. Croix, Virgin Islands		220,000
Grand total	5,459,500	440,000

TABLE 8.—Production and shipments of selected aluminum salts in the United States in 1963

Type of salt	Number of plants producing	Production (short tons)	Total shipments including interplant transfers	
			Short tons	Value (thousands)
Aluminum sulfate:				
Commercial (17 percent Al_2O_3)	58	947,546	945,569	$34,818
Municipal (17 percent Al_2O_3)	5	3,327		
Iron-free (17 percent Al_2O_3)	18	59,088	35,805	2,264
Aluminum chloride:				
Liquid (32° Bé)	10	26,637	13,076	1,052
Crystal (32° Bé)				
Anhydrous (100 percent $AlCl_3$)	6	23,136	23,347	5,540
Aluminum flouride, technical	6	81,446	81,132	22,182
Aluminum hydroxide, trihydrate (100 percent $Al_2O_3.3H_2O$)	9	226,953	212,330	15,033
Other inorganic aluminum compounds [1]	NA	NA	NA	13,924
Total	XX	XX	XX	94,813

NA Not available. XX Not eligible.

[1] Includes sodium aluminate, light aluminum hydroxide, cryolite, and alums.

Source: Data are based upon Bureau of the Census report Form MA-28E.1, Annual Report on Shipments and Production of Inorganic Chemicals.

STOCKS

Bauxite stocks in the United States on December 31, 1964, were 367,000 long dry tons less than at yearend 1963. By dry weight, consumers' inventories of crude and processed bauxite decreased 18 percent, and those at mines and processing plants increased 2 percent.

TABLE 9.—Stocks of bauxite in the United States [1]

(Long tons)

Year	Producer and processor		Consumer	
	Crude	Processed [2]	Crude	Processed [2]
1960	1,225,569	10,242	530,646	1,974,890
1961	1,306,419	9,466	621,729	1,897,635
1962	1,121,705	9,960	542,539	1,920,051
1963	1,143,893	8,967	499,526	1,696,700
1964	1,163,770	10,264	403,376	1,397,355

[1] Excludes strategic stockpile.
[2] Dried, calcined, and activated.

PRICES

No open market price was in effect for bauxite mined in the United States, because the output was consumed mainly by the producing companies.

The average value of bauxite shipped and delivered to domestic alumina plants was $16.33 per long ton, dry equivalent, for imported ore.

Prices per long ton quoted in E&MJ Metal and Mineral Markets for imported bauxite at yearend in 1963 and 1964 follow:

	Atlantic ports, f.o.b. cars	
	Dec. 30, 1963	*Dec. 28, 1964*
Calcined, crushed (abrasive grade) [1]	\$25.50–\$27.50	\$27.05–\$28.80
Refractory grade [2]	34.75	36.25
Dried bauxite, crushed chemical grade (60 percent Al_2O_3, 6 percent silica, 1.25 percent iron)	13.95	13.95

[1] 87 percent minimum Al_2O_3.
[2] 88 percent minimum Al_2O_3.

TABLE 10.—Average value of domestic bauxite in the United States [1]

(Per long ton)

Type	Shipments f.o.b. mines or plants		Type	Shipments f.o.b. mines or plants	
	1963	1964		1963	1964
Crude (undried)	\$9.57	\$9.55	Calcined	W	\$19.54
Dried	12.15	W	Activated	\$60.58	W

W Withheld to avoid disclosing individual company confidential data.
[1] Calculated from reports to the Bureau of Mines by bauxite producers.

The average value of calcined alumina, as determined from producer reports, was $0.0331 per pound. The value of imported calcined alumina and alumina products at the foreign port of shipment was $0.0268 per pound.

TABLE 11.—Average value of U.S. imports and exports of bauxite

(Per long ton)

Type and country	Average value port of shipment		Type and country	Average value port of shipment	
	1963	1964		1963	1964
Imports:			Imports—Continued		
Crude and dried:			calcined: [3]		
British Guiana	$8.98	$8.89	British Guiana	$25.06	$25.04
Dominican Republic [1]	12.89	14.36	Canada	--------	33.44
Germany, West	7.28	--------	Surinam	27.34	21.13
Greece	12.45	10.87	United Kingdom	--------	26.75
Haiti [1]	9.59	14.25			
Jamaica [1]	13.82	14.05	Average	25.41	24.28
Surinam [2]	[r] 10.29	9.80	Exports: Bauxite and bauxite concentrate	77.24	79.38
Average	12.44	12.65			

[r] Revised.

[1] Dry equivalent tons adjusted by Bureau of Mines used in computation.

[2] Surinam has been adjusted by the Bureau of Mines to include 73,333 long tons ($796,403) in 1963 and 43,366 long tons ($436,746) in 1964 reported as Trinidad and Tobago by the Bureau of the Census.

[3] For refractory use.

Source: Bureau of the Census.

NOTE.—Bauxite is not subject to an ad valorem rate of duty and the average values reported may be arbitrary for accountancy between allied firms, etc. Consequently the data do not necessarily reflect market values in the country origin.

TABLE 12.—Market quotations on alumina and aluminum compounds

Compound	Dec. 30, 1963	Dec. 28, 1964
Alumina, calcined, bags, carlots, works ... pound	$0.0530	$0.0530
Aluminum hydrate, heavy, bags, carlots, freight equalized ... do	.0370	.0370
Aluminum sulfate, commercial, ground, bulk, carlots, works, freight equalized ... ton	40.00	44.00
Aluminum sulfate, iron-free, bags, carlots, works, freight equalized ... 100 pounds	3.80	3.80

Source: Oil, Paint and Drug Reporter

FOREIGN TRADE

Imports.—Imports of bauxite, including ores acquired by the U.S. Government, totaled 11 percent more than in 1963. Imports from Jamaica, the principal source in recent years, were 12 percent more than in 1963 but 2 percent less than in the record year 1962, and remained at 57 percent of the total. Imports from Surinam increased 20 percent and was 30 percent of the total. The Dominican Republic, Haiti, and British Guiana accounted for most of the remaining imports.

TABLE 13.—U.S. imports for consumption of bauxite (crude and dried)[1] by countries

(Thousand long tons and thousand dollars)

Country	1955-59 (average)	1960	1961	1962	1963	1964
North America:						
Canada	---	---	---	(2)	---	---
Dominican Republic	77	632	722	719	729	640
Haiti	188	341	289	437	328	396
Jamaica	3,509	4,175	4,933	5,986	5,239	5,792
Total	3,774	5,148	5,944	7,142	6,296	6,828
South America:						
British Guiana	257	330	319	560	335	253
Surinam	2,706	3,256	2,912	2,858	[r][3]2,560	[3]3,070
Other	---	---	4	---	---	---
Total	2,963	3,586	3,235	3,418	[r]2,895	3,323
Europe	---	5	27	15	21	29
Africa	6	---	---	---	---	---
Grand total:						
Quantity	6,743	8,739	9,206	10,575	[r]9,212	10,180
Value	$57,132	$78,024	$88,814	$121,888	[r]$114,546	$128,787

[r] Revised.

[1] Import figures for Jamaican, Haitian, and Dominican Republic bauxite adjusted by Bureau of Mines to dry equivalent by deducting 13.6 percent free moisture for Jamaican, 14.6 percent for Haitian bauxite in 1957 and 13.6 percent in 1958 and later, and 17.7 percent for Dominican Republic. Other imports, which are virtually all dried, are on an as-shipped basis. Includes bauxite imported for Government account.

[2] Less than ½ unit.

[3] Surinam has been adjusted by the Bureau of Mines to include 73,333 long tons ($796,403) in 1963 and 43,366 long tons ($436,746) in 1964 reported by the Bureau of the Census as Trinidad and Tobago.

Source: Bureau of the Census.

TABLE 14.—U.S. exports of bauxite (including bauxite concentrates)[1] by countries

(Long tons)

Destination	1955-59 (average)	1960	1961	1962	1963	1964
North America:						
Canada	21,606	24,879	108,104	160,811	121,044	206,024
Mexico	943	2,781	562	826	20,245	30,863
Other	150	406	109	239	79	353
Total	22,699	28,066	108,775	161,876	141,368	237,240
South America	131	92	559	655	455	327
Europe	558	577	39,859	62,721	24,362	16,935
Asia	440	542	1,327	22,861	4,059	2,104
Africa	31	33	10	51	33	207
Oceania	---	7	153	10,397	32,919	36,729
Grand total as reported	23,859	29,317	150,683	258,561	203,196	293,542
Dried bauxite equivalent [2]	37,584	45,441	233,559	400,770	314,954	454,990
Value thousands	$1,800	$2,588	$12,189	$19,874	$15,696	$23,300

[1] Classified as "Aluminum ores and concentrates" by the Bureau of the Census.

[2] Calculated by Bureau of Mines.

Source: Bureau of the Census.

By dry weight, 44 percent of the imports entered through the New Orleans, La., customs district; 34 percent through the Galveston, Tex., district; 21 percent through the Mobile, Ala., district; and 1 percent through other districts.

Imports of aluminum oxides and compounds classified as aluminum hydroxides and oxides (alumina) totaled 210,644 short tons of which, 41 percent came from Japan, 30 percent from Guinea, 17 percent from Jamaica, and 10 percent from British Guiana. The remainder came chiefly from Canada, Austria, West Germany, France, and the United Kingdom.

Exports.—Exports of bauxite and bauxite concentrate increased 44 percent. Canada received 70 percent of the exports; Australia, 13 percent; Mexico, 11 percent; and France, 3 percent.

Approximately 48 percent of the 16,511 short tons of aluminum sulfate exported was shipped to Venezuela, and 43 percent was shipped to Canada, Mexico, Guatemala, the Canal Zone, the Dominican Republic, and Colombia. Of the 240,581 tons of other aluminum compounds exported, 75 percent was shipped to Norway and 14 percent was shipped to West Germany and Australia. Small quantities were shipped to 78 countries.

Tariff.—The duties on crude bauxite, calcined bauxite, and alumina imported for making aluminum were suspended until July 15, 1966. Duties on aluminum hydroxide and alumina not used for aluminum production were 0.25 cent per pound.

WORLD REVIEW

World bauxite production increased 10 percent. Jamaica, the principal producer, with an increase of 13 percent, accounted for 24 percent of the total. Surinam production increased 14 percent and accounted for 12 percent of the total, followed by France with a 19-percent increase. Australia more than doubled its 1963 output.

Alcan Jamaica, Ltd., shipped 2,000 tons of metal-grade bauxite from Jamaica to Spain for trial use and evaluation.

The first 6,300-ton shipment of alumina from Alcoa of Australia Pty., Ltd., Kwinana, Australia, was received in Japan by Mitsubishi Chemical Industries Ltd. early in 1963. Announcement was made that Mitsubishi will receive 60,000 tons of alumina per year for 2 years and 120,000 tons per year thereafter.

Worldwide the ratio of bauxite to aluminum production has declined as follows:

1955–59 (average)	6. 1
1960	6. 2
1961	6. 3
1962	6. 2
1963	5. 6
1964	5. 5

TABLE 15.—World production of bauxite, by countries[1]

(Thousand long tons)

Country	1955-59 (average)	1960	1961	1962	1963	1964[p]
North America (dried equivalent of crude ore):						
Dominican Republic	[2] 759	678	739	706	761	[3] 640
Haiti	[4] 266	268	263	370	327	373
Jamaica	4,246	5,745	6,663	7,495	6,903	[5] 7,811
United States	1,592	1,998	1,228	1,369	1,525	1,601
Total	6,863	8,689	8,893	9,940	9,516	10,425
South America:						
Brazil	68	119	110	188	167	[e] 165
British Guiana	2,076	2,471	2,374	3,035	2,342	2,468
Surinam	3,229	3,400	3,351	3,202	3,453	3,926
Total	5,373	5,990	5,835	6,425	5,962	6,559
Europe:						
Austria	22	26	18	17	18	4
France	1,620	2,035	2,190	2,160	1,997	2,387
Germany, West	4	4	4	5	4	4
Greece	749	870	1,100	1,300	1,261	1,279
Hungary	990	1,171	1,344	1,450	1,340	1,465
Italy	287	308	322	304	265	232
Rumania	58	87	68	30	10	[e] 10
Spain	7	3	6	6	12	[6] 12
U.S.S.R. [e]	2,460	3,500	4,000	4,200	4,300	4,300
Yugoslavia	809	1,009	1,213	1,311	1,265	1,273
Total [e]	7,006	9,013	10,265	10,783	10,472	10,966
Asia:						
China (diasporic) [e]	[7] 220	350	400	400	400	400
India	130	381	468	568	556	582
Indonesia	303	389	413	454	485	[e] 623
Malaysia:						
Malaya	291	452	410	349	444	464
Sarawak	[7] 172	285	253	225	155	165
Pakistan	2	1	1	---------	---------	---------
Total	1,118	1,858	1,945	1,996	2,040	2,234
Africa:						
Ghana (exports)	159	224	196	287	207	264
Guinea, Republic of	386	1,356	1,739	1,427	1,638	1,652
Mozambique	4	5	5	6	6	6
Rhodesia (formerly Southern)	---------	---------	---------	1	2	2
Sierra Leone	---------	---------	---------	---------	20	148
Total	549	1,585	1,940	1,721	1,873	2,072
Oceania: Australia	9	69	16	30	354	889
World total [e]	20,920	27,205	28,895	30,895	30,220	33,145

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[e] Estimate. [p] Preliminary.

[1] This table incorporates some revisions. Data do not add exactly to totals shown because of rounding where estimated figures are included in the detail.

[2] One year only as 1959 was the first year of commercial production.

[3] U.S. imports.

[4] Average annual production 1957-59.

[5] Bone dry equivalent of bauxite shipments and bauxite converted into alumina.

[6] 1963 data.

[7] Average annual production 1958-59.

TABLE 16.—Production and trade of bauxite in 1963, by major countries

(Thousand long tons)

Country	Production	Exports by country of destination											
		Total	North America		Europe							Asia (Japan)	All other countries
			Canada	United States	France	Germany, West	Italy	Spain	U.S.S.R.[1]	United Kingdom	Other Europe		
North America:													
Dominican Republic	761	932		932									
Haiti	327	[2] 379		[2] 379									
Jamaica	6,903	5,162		5,162									
United States	1,525	203	121		19	(3)	1	2		1	2	(3)	57
South America:													
Brazil	167	2											2
British Guiana	2,342	1,339	[4] 716	[4] 335	[4] 27	[4] 29	[4] 20	[4] 4			[4] 8	[4] 32	[4] 168
Surinam	3,453	3,427	486	2,929			[4] 2	6					4
Europe:													
Austria	18	7				7							
France	1,997	203				133	4			58	3		5
Germany, West	4	(3)					(3)				(3)		(3)
Greece	1,261	1,100		19	89	357		62	434	68	51		20
Hungary	1,340	656				[4] 89			[4] 567				
Italy	265												
Rumania	10	8							8				
Spain	12												
U.S.S.R.	[e] 4,300	NA											
Yugoslavia	1,265	982				692	225		63		2		
Asia:													
China (diasporic)	[e] 400	NA											
India	556	131				17	22		2	(3)		81	9
Indonesia	485	[4] 610				[4] 51						[4] 559	
Malaysia:													
Malaya	444	450										409	41
Sarawak	155	172										154	18
Africa:													
Ghana	[5] 207	207		8		21				178	(3)		
Guinea, Republic of	1,638	[4] 57	[4] 47			[4] 10							
Mozambique	6	NA											
Rhodesia (formerly Southern)	2												
Sierra Leone	20	20				10	10						
Oceania: Australia	354	143				15	22					106	
World total	[6] 30,220	16,190	1,370	9,764	135	1,431	306	74	1,074	305	66	1,341	324

[e] Estimate. NA Not available.
[1] U.S.S.R. and other Communist nations of East Europe. [2] U.S. imports. [3] Less than ½ unit. [4] Imports. [5] Exports.
[6] Data do not add exactly to total shown because of rounding where estimated figures are included in the detail.

TABLE 17.—World producers of alumina

(Short tons)

Country, company, and plant locations	Capacity, end of 1964	Participants
FREE WORLD		
North America:		
Canada:		
Aluminum Company of Canada, Ltd.: Arvida, Quebec.	1,270,000	Subsidiary of Aluminium, Ltd. (Canadian)
Jamaica:		
Jamaica, Ltd.:		
Kirkvine	560,000	Do.
Ewarton	310,000	
Total	870,000	
United States [1]	5,459,500	
Total, North America	7,599,500	
South America:		
Brazil:		
Aluminio Minas Gerais: Ouro Preto	32,000	Do.
Cie. Brasileira de Aluminio: Sorocaba	33,900	Industrias Votorantim S.A. 80 percent and other Brazalian interests, 20 percent.
Total	65,900	
British Guiana:		
Demerara Bauxite Co., Ltd.: MacKenzie.	331,000	Aluminium, Ltd. (Canadian).
Total South America	396,900	
Europe:		
France:		
Péchiney Compagnie de Produits Chimiques et Electrometallurgiques:		Privately owned (French).
Gardanne	443,000	
Salindres	220,000	
Soc. d'Electro-Chimie, d'Electro-Metallurgie et des Acieriés Electriques d'Ugine: La Barasse.	110,000	Do.
Societe Francaise Pour L'Industrie de L'Aluminium: St. Louis les Aygelades.	66,000	Affiliate of Aluminium-Industrie, A.G. (AIAG) (Swiss).
Total	839,000	
Germany, West:		
Aluminium G.m.b.H: Martinswerke	240,000	Subsidiary of Swiss AIAG.
Vereinigte Aluminium Werke A.G.:		
Lippewerk	143,000	Government owned.
Innwerk	121,000	
Gebrueder Giulini, G.m.b.H.: Ludwigshafen.	132,000	Privately owned (German).
Total	636,000	
Italy:		
Montecatini, Soc. Generale per l'Industrie Mineraria e Chimica.: Porto Marghera.	165,000	Montecatini group.
Soc. Alluminio Veneto per Azioni (SAVA): Porto Marghera.	110,000	Subsidiary of Swiss AIAG.
Total	275,000	
Norway: Norsk Aluminium A/S: Hoyander.	18,700	Privately owned (Norwegian) 50 percent, and Aluminium, Ltd. (Canadian) 50 percent.
Sweden: Svenska Aluminiumkomp A/B: Kubikenborg.	[2] 8,800	Privately owned (Swedish) 50 percent and Aluminium, Ltd. (Canadian) 50 percent.
United Kingdom:		
British Aluminium Co., Ltd		Tube Investments, Ltd. (British) 47 percent, Reynolds Metals Co. (American) 45 percent, Reynolds Tube Investments, Ltd., 14 percent, and miscellaneous shareholders, 4 percent.
Burntisland	67,200	
Newport	50,400	
Total	117,600	

See footnotes at end of table.

TABLE 17.—World producers of alumina—Continued

(Short tons)

Country, company, and plant locations	Capacity, end of 1964	Participants
FREE WORLD—Continued		
Europe—Contined		
Yugoslavia: State concerns		Government owned.
Lozorac	8,800	
Kidricevo (strnisce)	100,000	
Moste	8,800	
Total	117,600	
Total Europe	2,012,700	
Asia:		
India:		
Indian Aluminium Co., Ltd.: Muri	60,000	Indian owned 35 percent, Aluminium, Ltd. (Canadian), 65 percent.
Aluminium Corp. of India, Ltd.: Jaykaynagar.	11,000	Privately owned (Indian).
Hindustan Aluminium Corp. Ltd.: Renukoot.	44,000	Birla interests (Indian), 73 percent and Kaiser.
Madras Aluminium Co., Ltd.: Coimbatore.	22,000	Montecatini and private Indian interests.
Total	137,000	
Japan:		
Nihon Keikinzoku.: (Nippon Light Metal Co.) Shimizu.	298,000	Aluminium, Ltd. (Canadian) 50 percent, and privately owned (Japanese) 50 percent.
Showa Denko K.K. Yokohama	210,000	Privately owned (Japanese).
Sumitomo Kagaku K.K.: Kikumoto	210,000	Do.
Total	718,000	
Taiwan:		
Taiwan Aluminium Corp.: Takao	46,000	Government owned.
Total Asia	901,000	
Africa:		
Guinea: FRIA, Compagnie Internationale pour la Production d'Alumine.	530,000	Olin Mathieson Chemical Corp. (American), 48.5 percent; Péchiney-Ugine (French), 26.5 percent; British Aluminium Co., Ltd. (British) and Aluminium Industries, A.G. (Swiss) each 10 percent; and VAW (German) 5 percent.
Oceania:		
Australia:		
Comalco Industries Pty. Ltd.: Bell Bay.	56,000	Kaiser Aluminum & Chemical Corp. (American) 50 percent and Conzine Rio Tinto of Australia Ltd. 50 percent.
Alcoa of Australia Pty. Ltd.: Kwinana	230,000	Aluminum Company of America 51 percent and Western Aluminium N.L. (Australian) 49 percent.
Total Oceania	286,000	
Total free world	11,726,100	
SOVIET BLOC		
Europe:		
Germany, East:		
Vereinigte Aluminium Werke, A.G.: Lauta.	100,000	Government owned.
Hungary:		
Bonautaler Alaunnerde: Alamasfuzito	172,000	Do.
Ungarrische Bauxit Gruben A.G.: Ajaka.	66,000	Do.
Bauxit Industrie A.G.: Magyarovar	38,500	Do.
Total	276,500	

See footnotes at end of table.

TABLE 17.—World producers of alumina—Continued

(Short tons)

Country, company, and plant locations	Capacity, end of 1964	Participants
SOVIET BLOC—Continued		
Europe—Continued		
Rumania:		
Oradea	55,000	Government owned.
U.S.S.R.: Soviet Aluminium Trust:		
Achinsk	88,000	Do.
Boksitogorsk	165,000	Do.
Kamensk-Uralskiy	385,000	Do.
Kirovbad	220,000	Do.
Krasnotourinsk	385,000	Do.
Pikalëva	881,800	Do.
Volkhov	88,000	Do.
Zaporzhye	275,000	Do.
Pavlodar	550,000	Do.
Total	3,037,800	
Asia:		
China:		
Fushun	24,200	Do.
Nanting	44,000	Do.
Total	68,200	
Korea, North	(3)	
Total Soviet Bloc	3,537,500	
Total world	15,263,600	

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[1] For company and plant breakdown see table 6, this chapter.

[2] The plant is in standby condition. Some electrical parts have been removed.

[3] Data not available; capacity in 1943 was given as 75,500 tons.

NORTH AMERICA

Canada.—Allied Chemical Canada, Ltd., a subsidiary of Allied Chemical Corp., was building a liquid aluminum sulfate plant with a capacity in excess of 10,000 tons per year near Dalhousie, New Brunswick. The product will be available to pulp and paper mills in New Brunswick and to municipal waster purification plants in the Gaspé Peninsula area.

Additional facilities to expand capacity for refractory specialties were under construction at Oakville, Ontario, by Refractories Engineering and Supplies, Ltd., an affiliate of Kaiser Industries Corp.

Costa Rica.—An amendment to the Costa Rican Mining Code to regulate exploitation of aluminum-bearing ores became Law 3376 on August 25, 1964. Aluminum-bearing minerals were classified as a subsoil and therefore were the property of the State. Under the law a concession area for exploration and exploitation of aluminum minerals is limited to 6,178 acres; one-third of such an area, containing at least one-third of the mineral value, cannot be exploited under the original concession but may be the object of another concession for exploration and exploitation.

Payments by the contractor, required by the law, include a royalty to the State of 25 cents per dry metric ton, an ad valorem export duty of not less than 25 cents per dry metric ton, and a compensation of $0.05 per ton of dry raw material plus property damage to the property owner. The export duty is calculated by multiplying the percentage of Al_2O_3 in the raw material by a coefficient of $0.0385, which is based on a market price of $0.25 per pound of aluminum and adjusted proportionally to conform with price changes.

Jamaica.—As the world's major producer of bauxite, Jamaica accounted for 24 percent of the world total. Exports of 6 million long tons, or 75 percent of the total production, went to the United States. Alcan Jamaica Ltd. consumed the remainder and produced 832,000 short tons of alumina, 5 percent more than in in 1963.

Virgin Islands.—Harvey Aluminum was building a 220,000-ton alumina plant at St. Croix. The complex includes a deep-water port, a power generation plant, and a large sea water to fresh water conversion plant.

SOUTH AMERICA

Argentina.—A new company, Alprocsiro Argentine S.A. was organized to use a sulfuric acid process to produce alumina from a low-grade bauxite deposit with high silica content in northern Argentina.[3]

British Guiana.—Production of bauxite increased 5 percent. Demerara Bauxite Co., Ltd., shipped 533,000 long tons of dried bauxite, a 20-percent decrease from 1963 production; 463,000 tons of calcined bauxite, a 27-percent increase; and 292,000 tons of alumina, 32 percent more than in 1963. The company was building a $750,000 synthetic mullite plant with a capacity of 50,000 tons per year. Production was to begin early in 1965. Bauxite and alumina production will be increased with the development of a new mine on the west side of the Demerara River. A bridge between Mackenzie and Wismar, a new railroad, and a new plant to recover usable bauxite from accumulated tailings were under construction. The expansion also included installation of a new calciner at the plant and a walking drag at the new mine to strip overburden.

Reynolds Metals Co. planned to increase its mining capacity to more than 500,000 tons of bauxite per year.

Four experts prepared a report for the United Nations on possibilities of developing an aluminum industry in British Guiana.[4]

Surinam.—Exports of bauxite from Surinam amounted to 3,920,000 long tons, 14 percent more than in 1963. Of this the United States received 82 percent. Suriname Aluminum Co. (Suralco) furnished 63 percent of total 1964 exports.

The Surinam Bauxite Commission recommended the formation of a consortium consisting of N.V. Billiton Maatschappij, Suriname, Bridgeport Brass Co., Compagnie Belge pour l'Industrie del'Aluminium, Suriname Minerals Corp. (Ormet), and Suriname Aluminum Co. for exploitation of 647,000 acres of bauxite reserves in the Bakhuis Mountains area. The Commission also recommended that a 961,000-acre bauxite concession in the coastal plain of western Surinam be given to Harvey Aluminum Inc., and a 123,000-acre concession be granted to Reynolds Metals Co. The Brokopondo Agreement between Suralco and the Surinam Government would be the basis for new agreements.

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[3] Chemical Trade Journal and Chemical Engineering (London). Sulphuric Acid Process for Alumina Production. V. 155, No. 4036, Oct. 16, 1964, p. 517.

[4] Mining Journal (London). Hungarians Study British Guiana Bauxite. V. 262, No. 6719, May 29, 1964, p. 432.

Venezuela.—Over 4 million tons of bauxite reserves were indicated by the Ministry of Mines and Hydrocarbons of Venezuela.[5]

EUROPE

France.—Union des Bauxites, an affiliate of British Aluminium Co., Ltd., produced about 1,200 tons of bauxite per day from the "mine de Maron" in Var. The Newport alumina plant of British Aluminium Co., Ltd., in the United Kingdom, received the major part of the output.

Production capacity of alumina at the Gardanne plant of Péchiney, Compagnie de Produits Chimiques et Électrométallurgiques, was increased to 500,000 long tons per year with the addition of a fifth continuous extraction line.[6]

Hungary.—About 30,000 tons of alumina was exported to the U.S.S.R. Production of cryolite at the Magyarovar was increased from 600 tons to 900 tons per year.[7]

Hungarian metallurgists developed a pyrometallurgical process followed by magnetic separation to recover iron and caustic soda as well as alumina from bauxite. The process has been developed sufficiently to justify a pilot plant at Almasfuezitoi.[8]

Deposits of bauxite estimated at 80 million tons were discovered in western Hungary.

Rumania.—Electric powerlines from Beius to Dubresti and Lunca Spire were under construction to provide energy to exploit bauxite deposits in the Padurea Craiului Mountains.

U.S.S.R.—Construction of a 500,000-ton-per-year alumina plant at Pavlodar in northeast Kazakhstan was completed. Indications were that the alumina was for reduction plants near Noyokuznetsk, Irkutsk, and Kraznoyarsk.

Yugoslavia.—About 981,000 long tons of bauxite was exported. Of this, West Germany received 692,000 tons and Italy received 225,000 tons. About 13,000 tons of exported alumina was received by Poland and Austria.

ASIA

Japan.—During 1964 Japan imported about 1,596,000 long tons of bauxite. Of this, 605,000 tons came from Indonesia, 467,000 tons came from Malaysia, 253,000 tons came from Australia, and the remaining 271,000 tons came from Sarawak, British Guiana, India, Singapore, Surinam, and Saba (formerly North Borneo).[9]

Malaysia.—Malaya Acid Works Ltd., Petaling Jaya, Selangor, Malaya, was constructing an aluminum sulfate plant in Singapore using aluminum hydrate, probably inported from the United Kingdom. Output of the plant will be primarily for purification of Singapore's water supply. The Alumina Co., Ltd., a subsidiary of British Aluminum Co., Ltd., and Peter Spence and Sons, Ltd., a subsidiary of Laporte Industries, Ltd., designed the plant.

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[5] Foreign Trade (Canada). Venezuela. V. 121, No. 8, Apr. 18, 1964, p. 43.

[6] Light Metals. News From All Quarters — France. V. 27, No. 313, June 1964, p. 7.

[7] Mining Journal (London). Artificial Cryolite in Hungary. V. 263, No. 6831, Aug. 21, 1964, p. 136.

[8] Engineering and Mining Journal. Hungarian Metallurgists. V. 165, No. 12, December 1964, pp. 160, 166.

[9] Metal Bulletin (London). Japanese Bauxite Import Trends. No. 4986, Apr. 2, 1965, p. 28.

Taiwan.—In 1963 imports of bauxite amounted to about 52,200 long tons. Of this, Saba (formerly North Borneo) furnished 36,400 tons and Malaysia furnished 15,400 tons.

AFRICA

Guinea, Republic of.—Harvey Aluminum, Inc., had a 51-percent interest in a new company, Compagnie des Bauxites de Guinée, organized at Conakry, Guinea, for development of the Boké bauxite deposit. The Republic of Guinea held the remaining 49 percent. The U.S. Agency for International Development had approved the project and had issued investment guarantees. The deposit was estimated to contain 1 billion tons of bauxite. Starting date for mining is dependent on completion by the Government of railway and port facilities.[10]

Sierra Leone.—The Mokanji bauxite mine, operated by Sierra Leone Ore & Metal Co., produced bauxite at the rate of about 10,000 tons per month and planned to double output by 1965.

OCEANIA

Australia.—A loan of $117 million was secured from 11 U.S. banks headed by Mellon National Bank and Trust as interim finance for construction of the Gladstone alumina plant of Queensland Alumina, Ltd., which will have a capacity of 675,000 tons per year. Kaiser Aluminum & Chemical Corp. owned 52 percent of the plant; Alcan Queensland Pty., Ltd., and Péchiney, Compagnie de Produits Chimiques et Électrométallurgiques each owned 20 percent; and Conzinc Rio Tinto of Australia, Ltd., owned the remaining 8 percent.[11]

The Queensland Government in Australia increased its royalty from 5.6 to 11.2 cents per ton on all bauxite exports except shipments to Bell Bay, Tasmania.

Comalco (Commomwealth Aluminium Corp., Pty., Ltd.) announced plans to expand facilities at Weipa, including constructing a new wharf site with a traveling slewing shiploader and dredging the present 27-foot-deep channel to a 33-foot-deep channel.[12]

The Australian Government extended the closing date for tenders to establish an aluminum complex on the Gove Peninsula of the Northern Territory to March 15, 1965, at the request of interested companies. Previous tenders did not meet all Government conditions, such as participation of Australian interests and location of the smelter in Australia.[13]

The 210,000-ton Kwinana alumina plant on the west coast owned by Alcoa of Australia was equipped to load 750 tons of bulk alumina per hour into 10,000-ton bulk carriers for transportation to the Geelong aluminum smelter at Victoria.[14]

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[10] American Metal Market. Harvey Aluminum Joins in Forming Company To Mine Vast Ore Reserves. V. 71, No. 128, July 2, 1964, p. 17.

[11] Engineering and Mining Journal. Construction To Start on Queensland Alumina Plant. V. 165, No. 5, May 1964, p. 130.

[12] American Metal Market. Comalco Aluminium Gears for Full-Scale Bauxite Mining at Weipa. V. 71, No. 181, Sept. 17, 1964, p. 12.

[13] Chemical Week. Australian Government Extends Data for Aluminum Complex Bids. V. 95, No. 23, Dec. 5, 1964, p. 108.

Bauxite for the plant, mined from the Jarrahdale deposit of aluminous laterite, contains 35 percent alumina in the trihydrate form. The ore is trucked to the crusher and conveyed by belt to two 750-ton railway bins. Sixty aluminum hopper cars transport the bauxite to the plant.

TECHNOLOGY

Interest in development of processes for extraction of alumina from low-grade and nonbauxite materials continues, and technical research on composition, structure, and properties of alumina ceramics was accelerated by the demand for superduty refractories.

The Bureau of Mines released a publication in a series of reports on cost evaluation of processes for the production of metallurgical-grade alumina from low-grade aluminous materials.[15] Relative operating costs, based upon previously published pilot plant and laboratory studies, were estimated at $60.69 per ton of alumina for a nitric acid process for a plant producing 1,000 tons per day using clay at $1 per ton.

A description was published of the methods and costs of the lime-soda-sinter process used at Laramie, Wyo., to produce alumina from anorthosite with a residue suitable for manufacture of portland cement.[16] The estimated cost, based on a 200-ton-per-day alumina plant, was $105.68 per ton including fixed charges. With a credit of $42.20 for the production of cement from the residue, the net cost was $63.48 per ton of alumina.

Solubility characteristics of three calcium aluminates, $12CaO.7Al_2O_3$, $3CaO.Al_2O_3$, and $4CaO.Al_2O_3.Fe_2O_3$, prepared by sintering stoichimetric mixtures at 1,375° F, were published.[17]

A study was made to determine properties and characteristics of sodium aluminate in relation to the lime-soda-sinter process and optimum alumina recovery.[18] Additional sodium hydroxide, over that supplied by the sodium aluminate, was required for maximum extraction of aluminum. The precipitation of alumina trihydrate from sodium aluminate was part of a continuous reversible reaction.

A flocculent comprising 40 to 80 percent of a bivalent lead compound for settling insoluble ores in digested bauxite slurries was patented.[19]

Intepretation of an aeromagnetic survey, east-south-east of Little Rock, Ark., indicated geologic conditions similar to those in the vicinity of bauxite deposits.[20] The report of the survey suggests the existence of a mepheline-syenite body of rocks a few hundred feet below the surface.

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[14] Foreign Trade (Canada). Aluminum—Australia. V. 121, No. 10, May 16, 1964, p. 27.

[15] Johnson, Paul W., Frank A. Peters, and Ralph C. Kirby. Methods for Producing Alumina From Clay. An Evaluation of a Nitric Acid Process. BuMines Rept. of Inv. 6431, 1964, 25 pp.

[16] Diehl, Kent B. Cement and Alumina From Anorthosite. Minerals Proc., v. 5, No. 7, August 1964, pp. 14–16.

[17] Lundquist, R. V., and H. Leitch. Aluminum Extraction Characteristics of Three Calcium Aluminates in Water, Sodium Hydroxide, and Sodium Carbonate Solutions. BuMines Rept. of Inv. 6528, 1964, 16 pp.

[18] Lundquist, R. V., and H. Leitch. Solubility Characteristics of Sodium Aluminate. BuMines Rept. of Inv. 6504, 1964, 19 pp.

[19] Cook, George W. (assigned to Reynolds Metals Co.). Flocculating Agent and Process for Digested Bauxite Slurries. U.S. Pat. 3,142,637, July 28,1964.

[20] Jespersen, Anna. Aeromagnetic Prospecting for Bauxite Deposits in the Mississippi Embayment, Arkansas and Missouri. Geol. Survey Geophysical Investigations Maps GP-370, U.S. Dept. Interior News Release, July 15, 1964.

A study was published describing the bauxite deposits in Georgia, Alabama, Tennessee, Virginia, and Mississippi. Since 1888, production from the area has totaled about 2.7 million long tons. The major reserves are in Georgia and Alabama and total about 1 million long tons. An additional 55,000 long tons is found in the other 3 States.[21]

The British Aluminium Co., Ltd., is recovering bauxite by open pit mining from two deposits in Ghana on Konaiyeribo and Ichiniso Hills. The topsoil, 5 to 8 feet thick, is stripped and loaded with a back hoe into 4.5-cubic-yard dump trucks. The underlying bauxite, ranging from 50 to 150 feet thick, is drilled with churn drills for blasting. Fragmentation is poor and secondary blasting is required. The bauxite is loaded by power shovels into 13-cubic-yard dumpers and transported to a 36- by 24-inch jaw crusher. A belt conveyer transfers the crushed ore to buckets on an 8,000-foot-long ropeway for transportation to a washing plant. After scrubbing, the bauxite is screened and sized. The plus 1/16 inch goes to the railway bin, and the minus 1/16 inch goes to a classifier for removal of slimes before going to the railway bin. All stages of the operation are designed for 185 or more tons per hour. The Ghana Railway delivers the ore to a bulk loading installation at Takoradi Harbor.[22]

Two articles describing the present and planned exploitation of bauxite deposits in Jamaica by Alcoa Minerals of Jamaica, Inc., Alcan Jamaica, Ltd., Reynolds Jamaica Mines, Ltd., and Kaiser Bauxite Co. were published.[23]

Alcoa mines bauxite in Clarendon Parish, Jamaica, with shovels equipped with 2.5 cubic yard dippers: using open pit methods, and transports it in 30-ton trucks over well-graded roads to the load-out ramp at Woodside. The ore is loaded into 86-ton aluminum hopper cars for haulage over an 18.5-mile railroad to an open storage area at Rocky Point where a rotary dumper unlaods one car per minute and feeds a 175-foot conveyer which carries the ore to a conveyor-stacker. The ore is removed from the stock pile via an underground drawpoint for screening out the plus 4-inch limestone before entering a 250-ton-per-hour dryer where the moisture is reduced from 21 percent to 16 percent. After a 1.25-inch screening the material is conveyed to a radial stacker for storage in a 67,000-ton-capacity aluminum-doomed shed, 100 feet high and 300 feet in diameter, where it is kept dry until loaded by a bucket-wheel reclaimer onto a ship-loading conveyor with a 2,000-ton-per-hour capacity leading to a 38-foot-deep channel, where 34,000-ton ships are loaded for the trip to Point Comfort.

Alcan operates two open pit mines, one at Kirkvine in Manchester Parish and the other near Ewarton in St. Ann Parish. At both places the ore is broken with rippers, loaded, and hauled with scraper-haulers. Draglines with 5.5 cubic yard buckets often load the scraper-haulers, which are equipped with 36-inch side boards. Some pits with good drainage are reserved for operating during wet weather. Selective mining is practiced.

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[21] Overstreet, Elizabeth F. Geology of the Southeastern Bauxite Deposits. U.S. Geol. Survey Bull. 1199, 1964, 19 pp.

[22] Bureau of Mines. Mineral Trade Notes. V. 58, No. 5, May 1964, pp. 5–9.

[23] Engineering and Mining Journal: Jamaica Planning for Versatile Mining. V. 165, No. 3, March 1964, pp. 78–79. Engineering and Mining Journal: Jamaica Keeps Growing—Two New Projects Will Boost Bauxite Shipments to the U.S. V. 165, No. 1, January 1964, pp. 50–57.

At Kirkvine the scraper-haulers dump into 11 storage bays at the alumina plant for processing into alumina. About 4,000 long tons of bauxite ore is mined per day, producing about 1,500 short tons of alumina. "Tear-drop" design hopper cars are loaded from 2,000-ton silos for a 32-mile haul to Port Esquivel on the south coast, where the alumina is stored in four silos with a total capacity of 50,000 tons. The alumina is subsequently loaded into 12,000- to 20,000-ton ships via conveyors and trimmers.

At Ewarton a 300-ton per-hour aerial tramway transports the ore to the alumina plant, where about 2,300 long tons of bauxite is processed into 840 short tons of alumina. The alumina is transported by rail to Port Esquivel and handled in the same way as the ore from Kirkvine. About 65 percent of the Kirkvine-Ewarton tonnage goes to Kitimat, British Columbia, and Arvida, Quebec, in Canada, and 35 percent goes to Norway, Sweden, and Switzerland.

In St. Ann Parish, Reynolds maintains extra pits as alternate sites for wet weather operations and for blending purposes. Blastholes, 4.5 inches in diameter, are loaded with AN–FO prills (ammonium nitrate-fuel oil) for breakage. About 2 million tons per year is produced. Shovels and draglines load the ore into rear dump and bottom dump tractor-trailers for haulage to a common stockpile from which the ore is fed into two pairs of kilns after screening. One pair feeds a 2,500-ton live storage bin and the other a 16,000-ton bin. The partially dried ore is transported by aerial tramway to Ocho Rios on the north side of Jamaica where 32,000-ton ships with 39-foot draw are loaded at 4,400 tons per hour by a boom.

Kaiser mines an area in St. Elizabeth Parish near Spur Tree about 25 miles west of Kirkvine. Pits producing about 19,600 long tons per day and averaging about 25 feet deep are mined with shovels and draglines. Haulage to the railroad ramp is by truck. Well-drained pits, close to the ramps, are reserved for wet weather operations.

About 1.5 hours is required to load and transport ore in a 20- to 25-car train of 75- to 84-ton aluminum gondola cars to Port Kaiser on the south side of Jamaica, where a rotary dumper unloads the ore for conveying to a 150,000- to 200,000-ton stockpile. The ore is bulldozed to four drawpoints and then conveyed to four kilns, where the moisture is reduced to 15 or 16 percent. Each kiln can handle 200 tons per hour. The bauxite is screened before storage in storage sheds, which hold 88,000 tons. A 5-million-ton-per-year output is maintained to load three or four ships per week of 37,600-ton capacity each.

Kaiser is constructing a new port at Discovery Bay in St. Ann Parish on the north side of Jamaica to handle bauxite mined in that parish and in Trelawny Parish.

Plans are at an early stage, but the property will be developed in increments of 1.5 million tons per year. The Spur Tree operation is being used as a general guideline for planning recovery of the north side bauxite.

Tests were conducted for slag corrosion evaluations correlated to porosity, permeability, and pore size of alumina-silica refractories, without changing the chemical properties.[24] Results showed that a maximum amount of solid material, or a minimum amount of void volume, offered the maximum resistance to slag corrosion. Both size and number of pores affected permeability.

Experiments showing the relative importance of heat and humidity were conducted to determine the effects of curing methods on the strength of refractory concretes.[25]

A foamed-in-place refractory material, with good thermal properties at temperatures up to 3,500° F., was prepared by mixing at room temperature a slurry of 35 to 55 percent orthophosphoric acid, 35–55 percent aluminum hydroxide, 1.5 to 4.5 percent bentonite, 0 to 15 percent aluminum metaphosphate, 0.1 to 0.7 percent metal powder, and 0 to 5 percent silica powder. The slurry was cured for 12 hours at about 185° F.[26]

Single-crystal sapphire fibers having a tensile strength of more than 3 million pounds per square inch have been made experimentally. Suggested uses are ultrastrong plastic laminates and thin ceramic laminates.[27]

An article described the desirable and undesirable effects of four types of alumina refractories as applied to electric glass-melting furnaces.[28] Two zirconia-silica types offered high resistance to glass attack and high electric resistivity. In two with no zirconia and less than 2 percent silica, the alphabeta alumina type was less resistant to glass corrosion and more electrically conductive. The chromite-alumina type was extremely high in resistance to the glass corrosion and in electrical resistivity, but the chromic oxide content left open the possibility of glass discoloration.

The procedures used to determine the behavior of commercial calcium aluminate cements when subjected to disintegration by carbon monoxide were described.[29] Resistance varied within a wide range of service life. Resistance of high-purity cements to disintegration was similar to that of superduty fire-clay brick. Low-purity cements had poor resistance, intermediate cements ranged from poor to good, depending, probably, on chemical form and coarseness of distribution of the catalytic impurities.

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[24] Vojnovich, Theodore, Thomas D. McGee, and C. M. Dodd. Correlation of Slag Resistance With the Pore Structure of an Alumina-Silica Refractory. Am. Ceram. Soc. Bull., v. 43, No. 7, July 1964, pp. 514–517.

[25] Wygant, J. F. and M. S. Crowley. Curing Refractory Castables: It isn't the Heat, It's the Humidity. Am. Ceram. Soc. Bull., v. 43, No. 1, January 1964, pp. 1–5.

[26] Materials in Design Engineering. Foamed Aluminum Refractory Takes 3,500° F. V. 60, No. 1, July 1964, p. 113.

[27] Chemical Week. Superstrong Sapphire Whiskers Have Been Made Into Paper. V. 95, No .8, Aug. 22, 1964, p. 90.

[28] Nelson, J. R. and W. R. Miller. The Jeannette Glass Story: Refractories For Electric Glass Melting. Ceramic Age, v. 80, No. 3, March 1964, pp. 48–50.

[29] Gitzen, W. H., R. P. Heilich, and Frank J. Rohr. Carbon Monoxide Disintegration of Calcium Aluminate Cements in Refractory Castables. Am. Ceram. Soc. Bull., v. 43, No. 7, pp. 518–522.

Laboratory tests show that by careful evaporation waste materials or byproducts in the form of dilute hydrofluoric acid (HF) and ammonium fluoride (NH_4F) solutions, usually from plants that treat phosphate rock, can be slurried with alumina hydrate to precipitate hydrated aluminum fluoride (AlF_3) or ammonium aluminum fluoride ($(NH_4)_3\ AlF_6$). These precipitates were converted to anhydrous AlF_3 by controlled heating.[30]

At Linz, Austria, a process was developed to produce aluminum fluoride by reacting aluminum hydroxide ($Al(OH)_3$) with hydrofluosilicic acid (H_2SiF_6), a byproduct in the manufacture of superphosphates. The acid was produced by passing volatile SiF_4 through a series of scrubbers:

$$3SiF_4+2H_2O\rightarrow 2H_2SiF_6+SiO_2 \text{ and } H_2SiF_6+2Al(OH)_3\rightarrow 2AlF_3+SiO_2+4H_2O.$$

After the hydrated silica was precipitated, $AlF_3\cdot 3H_2O$ was crystallized from the mother liquor and calcined to yield anhydrous AlF_3.[31]

A process was patented to produce sodium aluminate and hydrogen fluoride by sintering domestic high-silica aluminous ores, fluorspar, and soda ash in the presence of water vapor. The sodium aluminate was leached with dilute caustic and processed to alumina. Fluoride and cryolite were produced from the hydrogen fluoride.[32]

A process to remove sulfuric acid as an impurity from liquid sulfur dioxide by contact with granular calcined bauxite was patented.[33]

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[30] Blake, Henry E., and Robert K. Koch. Preparation of Aluminum Fluoride From Alumina Hydrate and Dilute Fluoride Solutions. BuMines Rept. of Inv. 6524, 1964, 17 pp.

[31] Weinrotter, Ferdinand. Now Commercial: AlF_3 Synthesis From Superphosphate Byproduct. Chem. Eng., V. 71, No. 9, pp. 132–134.

[32] Hrishikesan, Kizhakke G. (assigned to Reynolds Metals Co.). Method for the Concurrent Production of Alkali Metal Aluminate and Hydrogen Fluoride. U.S. Pat. 3,116,971, Jan. 7, 1964.

[33] Young, David George (assigned to Stauffer Chemical Co.). Process for Purifying Liquid Sulfur Dioxide With Bauxite. U.S. Pat. 3,141,735, July 21, 1964.

Beryllium

By Donald E. Eilertsen [1]

◆

DOMESTIC beryl output continued at a very low level in 1964. Sharp declines in consumption, imports, and world production of beryl and also output of beryllium metal occurred, but there was a substantial increase in the output of beryllium-copper master alloy, in contrast to 1963.

LEGISLATION AND GOVERNMENT PROGRAMS

No beryl or beryllium-copper master alloy was acquired in 1964 for stockpiling under the Strategic and Critical Materials Stockpiling Act of 1946 (Public Law 520, 79th Cong.).

Under the Agricultural Trade Development and Assistance Act of 1954, surplus agricultural commodities were bartered for beryl and beryllium metal. During 1964, a quantity of beryl and 8 tons of beryllium metal were added to the inventories of Commodity Credit Corporation (CCC) and the supplemental stockpile.

The Office of Minerals Exploration, U.S. Department of the Interior, offered financial assistance up to 50 percent of approved costs to explore for all types of beryllium ore. No new contract for beryllium exploration was made in 1964.

TABLE 1.—Salient beryl statistics

	1955–59 (average)	1960	1961	1962	1963	1964
United States:						
Beryl, approximately 11 percent BeO unless otherwise stated:						
Domestic beryl shipped from mines short tons	451	244	317	218	1	W
Other domestic low-grade beryllium ore short tons	(1)	265	805	760	750	----------
Imports do	7,667	8,943	8,516	8,552	6,243	5,425
Consumption do	5,337	9,692	9,392	7,758	7,934	4,435
Price, approximate, per unit BeO imported, cobbed beryl at port of exportation	$31	$29	$30	$31	$24	$23
World: Production short tons	10,600	12,300	12,900	11,000	7,700	5,700

W Withheld to avoid disclosing individual company confidential data.

[1] Material first available in 1958; 1958, 42 short tons, and 1959, 97 short tons.

DOMESTIC PRODUCTION

Mine Production.—Hand-sorted beryl was produced in South Dakota, Colorado, and Wyoming. The quantity produced was small; data company confidential.

Refinery Production.—The Beryllium Corp. of Reading and Hazleton, Pa., and The Brush Beryllium Co. of Elmore, Ohio, processed hand-sorted beryl into beryllium metal, alloys, and compounds; output was mostly beryllium-copper master alloy and beryllium metal. Output of beryllium metal was much smaller in 1964 than in 1963; the sharp decline was mostly due to the completion of Government contracts in 1963 for stockpile beryllium. Production data are company confidential.

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[1] Commodity specialist, Division of Minerals.

Beryllium Metals & Chemicals Corp., Bessemer City, N.C., a subsidiary of Lithium Corporation of America, Inc., produced some electrorefined beryllium.

The Brush Beryllium Co. continued its economic studies on extracting beryllium from its large bertrandite deposit in Utah.

The Anaconda Company announced that it began to produce electrorefined beryllium and reportedly continued its studies on the utilization of Utah beryllium ore.

CONSUMPTION AND USES

Cobbed beryl consumption was 4,435 tons and the smallest since 1957. Most of this beryl was processed into beryllium metal, alloys, and compounds.

Sales of The Beryllium Corp. were $24.8 million, compared with $28.2 million in 1963. The Brush Beryllium Co. sales were $22.4 million, compared with $24.3 million in 1963.

Other consumers of cobbed beryl were Beryl Ores Co., Arvada, Colo., which produced specialized beryl materials for the ceramic industry; Lapp Insulator Co., LeRoy, N.Y., which used ground beryl in making high-voltage electrical porcelain; and the Ceramic Division, Champion Spark Plug Co., Detroit, Mich., which used beryl as a minor constituent in special ceramic compositions, principally spark plugs.

Beryllium metal applications were mostly in nuclear reactors, high-speed flight, missiles, and space exploration, and in research and development, particularly in the aerospace categories. Numerous uses for beryllium metal are gradually emerging from intense research and development which have been underway in recent years. Some recently developed uses for beryllium metal include windows in small portable X-ray units, neutron reflector for a high flux isotope reactor, compact components of guidance systems for missiles and spacecraft, a receptacle to hold silicon solar cells, skin panels for space vehicles, housing and base for an astronavigational sextant and scanning telescope, parts for missiles, torque tubes in fighter aircraft, and brakes on aircraft and on a racing car.

Beryllium additives to rocket fuels continued to be studied.

Beryllium copper alloys had many diverse applications such as in high-speed flight, telephone systems, automobiles, and electronics. Some new uses included parts of helicopter rotars, springs for submarine hatch covers, bushings and trunnion bearings in the landing gear of high-speed aircraft, contact springs for automobile light switches, keys for woodwind instruments, valve body in portable air compressors, high pressure tanks used in high energy research physics, the shell of a magnetohydrodynamic cesium generator under development, and for thousands of jobs such as miniature connectors used in electronic and electrical devices, some of the parts so small that 50 could be hidden under a dime. New beryllium aluminum alloys containing mostly beryllium continued to attract attention. New applications of beryllium oxide in the electronic field and in nuclear energy continued to develop.

STOCKS

Consumers stocks of beryl at yearend totaled 7,200 tons.

Government yearend stocks of beryl, beryllium metal, and beryllium copper are shown in table 2.

TABLE 2.—Government yearend stocks of beryllium-bearing materials

(Short tons)

Items	Strategic stockpile	Defense Production Act (DPA)	Commodity Credit Corp. (CCC) and Supplemental stockpile	Total
Stockpile-grade beryl (equivalent beryl)	23,230	2,086	[1] 18,395	[1] 43,711
Nonstockpile-grade beryl	----------	456	----------	456
Breakdown of stockpile grade of equivalent beryl consisted of the following:				
Beryl on hand	21,734	2,086	3,369	27,189
Beryllium-copper master alloy	1,075	----------	6,312	7,387
Beryllium	----------	----------	153	153

[1] Does not include 6,000 tons of beryl on order.

Source: Statistical Supplement Stockpile Report to the Congress, July–December 1964, prepared by General Services Administration.

PRICES AND SPECIFICATIONS

Prices for domestic and imported cobbed beryl were on a buyer and seller basis.

The price of beryllium metal, 97 percent pure, lump or beads, f.o.b. Reading, Pa., and Cleveland, Ohio, was quoted at $62 per pound in 1,000- to 2,000-pound quantities. A blend of beryllium powder, 200-grade, was quoted at $54 per pound in quantities of 20,000 pounds. Vacuum-cast beryllium ingot was quoted at $67 to $71 per pound. Beryllium-copper master alloy was quoted f.o.b. Reading, Pa., Detroit, Mich., and Elmore, Ohio, at $43 per pound of contained beryllium with copper paid for at the market price on date of shipment. Beryllium-copper strip, rod, bar, and wire were quoted at $2.01 per pound until February 19 and thereafter at $2.04 per pound. Beryllium-aluminum was quoted at $65 per pound of contained beryllium with aluminum paid for at the market price. Beryllium-magnesium-aluminum was quoted at $60 per pound of contained beryllium with magnesium and aluminum paid for at the market price.[2]

The Brush Beryllium Co. quoted prices for UOX and GC–R beryllium oxide powders, minus 20-mesh size, dry screened, of $12 to $15 per pound, depending upon the quantity.

FOREIGN TRADE

Twenty-eight pounds of beryllium ore or concentrate valued at $600, was exported to South Korea. No export data were available on beryllium-copper alloy.

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[2] American Metal Market. V. 71, Nos. 1–252, January–December 1964.

TABLE 3.—U.S. imports for consumption of beryl, by countries and customs districts

(Short tons)

Country and customs district	1963	1964
South America:		
Agentina:		
New York	----------	46
Philadelphia	718	383
Total	718	429
Bolivia: Philadelphia	33	----------
Brazil:		
Maryland	24	----------
New York	----------	128
Philadelphia	2,256	1,768
Total	2,280	1,896
Total South America	3,031	2,325
Europe:		
Finland: Philadelphia	----------	3
Sweden: Philadelphia	----------	49
Total Europe	----------	52
Asia: Pakistan; Philadelphia	----------	13
Africa:		
British East Africa and Tanganyika: Philadelphia	[1] 664	----------
Burundi and Rwandi: Philadelphia	510	101
Congo (Léopoldville): Philadelphia		224
Malagasy Republic: Philadelphia	324	297
Malawi, Southern Rhodesia, and Zambia: Philadelphia	347	384
Mozambique: Philadelphia	850	716
South Africa, Republic of:		
New York	39	----------
Philadelphia	355	660
Total	394	660
Uganda: Philadelphia	----------	411
Total Africa	3,089	2,793
Oceania: Australia: Philadelphia	123	242
Grand total	6,243	5,425
Value	$1,671,590	$1,372,160

[1] Believed to be principally Uganda.

Source: Bureau of the Census.

TABLE 4.—Imports of beryllium products, in 1964, by countries

Country	Beryllium: unwrought, waste, and scrap		Wrought beryllium		Beryllium oxide or carbonate		Other beryllium compounds	
	Pounds	Value	Pounds	Value	Pounds	Value	Pounds	Value
France	7,539	$427,718	36	$2,253	--------	--------	3,954	$18,976
Germany, West	32,065	7,040	--------	--------	--------	--------	--------	--------
Japan	--------	--------	--------	--------	40	$792	--------	--------
Spain	6,315	3,425	--------	--------	--------	--------	--------	--------
Switzerland	2,440	494	--------	--------	--------	--------	--------	--------
United Kingdom	7,210	2,975	--------	--------	(1)	379	--------	--------
Total	55,569	441,652	36	2,253	40	1,171	3,954	18,976

[1] Less than ½ unit.

Source: Bureau of the Census.

TABLE 5.—U.S. exports of beryllium products, in 1964, by countries

Destination	Beryllium and beryllium alloy (except beryllium copper) metal powders		Beryllium metal and alloys (except beryllium copper) in crude form and scrap		Beryllium and beryllium alloys in semifabricated forms, n.e.c.	
	Pounds	Value	Pounds	Value	Pounds	Value
Austria	-----	-----	6,875	$21,338	4	$788
Australia	-----	-----	1,759	5,668	(1)	106
Brazil	18	$640	-----	-----	-----	-----
Canada	550	1,670	17,674	26,527	56	17,710
France	-----	-----	-----	-----	95	16,722
Germany, West	62	2,456	68,535	202,112	41	6,119
India	-----	-----	227	10,872	6	1,936
Italy	-----	-----	2,241	7,236	-----	-----
Ivory Coast	444	766	-----	-----	-----	-----
Japan	1,620	65,839	1,590	35,537	-----	-----
Mexico	2,368	380	442	1,662	-----	-----
Netherlands	-----	-----	220	858	2	426
Norway	-----	-----	39,981	52,598	-----	-----
South Africa, Republic of	90	508	-----	-----	-----	-----
Spain	-----	-----	1,103	3,760	2	512
Switzerland	8	328	3,644	10,089	3	1,201
Turkey	-----	-----	426	1,290	-----	-----
United Kingdom	837	55,138	17,530	67,195	13	2,409
Yugoslavia	-----	-----	2,205	6,680	-----	-----
Total	5,997	127,725	164,452	453,422	222	47,929

[1] Less than ½ unit.

Source: Bureau of the Census.

WORLD REVIEW

World production of beryl is shown in table 6.

Afghanistan.—Soviet geologists and personnel from the Afgan Ministry of Mines and Industries discovered two beryllium deposits in the Noor and Paich Valleys east of the Kunar River.[3]

Japan.—During 1963, Nippon Gaishi Kaisha, Ltd., and Yokosawa Kagaku Kogyo (Yokosawa Chemical Co., Ltd.) were reported to have produced a total of 150 metric tons of beryllium-copper master alloy and 50 tons of beryllium oxide. Japan imported beryl mostly from Southern Rhodesia and Mozambique, and imported about 2 tons of lump beryllium, 300 tons of beryllium scrap (presumably beryllium-copper), and 5 tons of other beryllium products (probably beryllium-copper) from the United States.[4]

The monthly production potential of the three producers of beryllium were reported.[5] Nippon Gaishi Kaisha, Ltd., can produce 30 kg of beryllium by electrorefining methods and 20 metric tons of beryllium-copper master alloy and 3 tons of beryllium oxide by the silicofluoride process per month. This firm also can produce 5 tons of beryllium-copper castings and forgings, 5 tons of safety tools, and 5 tons of beryllium-copper electrodes per month. Yokosawa Chemical Co., Ltd., can produce 10 kg of beryllium by electrorefining methods and also 10 metric tons of beryllium-copper master alloy and 1 ton of beryllium oxide by the sulfate process per month. This company also can produce 2 tons of beryllium-copper castings and forgings and 2 tons of beryllium-copper electrodes per month. Santoku Kinzoku Kogyo (Santoku Metal Industry Co., Ltd.), can produce 2 metric tons of beryllium-aluminum master alloy containing 3 to 5 percent beryllium per month.

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[3] Bureau of Mines. Mineral Trade Notes. V. 59, No. 6, December 1964, p. 10.

[4] Bureau of Mines. Mineral Trade Notes. V. 60, No. 2, February 1965, pp. 6–7.

[5] Japan Society of Newer Metals, Tokyo. Current Situation of Newer Metals in Japan, 1964, 45 pp.

TABLE 6.—World production of beryl by countries

(Short tons)

Country	1955–59 (average)	1960	1961	1962	1963	1964 [p]
Argentina	1,824	[1] 1,157	[1] 1,488	[1] 998	[1] 825	[2] 429
Brazil	2,165	3,827	3,503	3,319	2,169	[2] 1,896
Congo (Léopoldville)	1,015	369	184	304	235	[2] 224
Malagasy Republic	288	701	836	743	453	[1] 157
Mozambique	1,299	1,649	1,073	627	613	422
Southern Rhodesia	583	539	396	559	249	182
Uganda	121	470	1,136	1,116	419	[1] 450
U.S.S.R. [e]	250	750	900	1,000	1,100	1,100
Other	3,055	2,838	3,384	2,334	1,637	[3] 860
Total	10,600	12,300	12,900	11,000	7,700	5,700

[e] Estimate.
[p] Preliminary.
[1] Exports.
[2] United States imports.
[3] Comprises Australia, Burundi and Rwanda, Portugal, Republic of South Africa, South-West Africa Sweden, and United States.

TECHNOLOGY

Defense agencies and the National Aeronautics and Space Administration continued to delve deeper into the technology of beryllium for possible larger use of the metal in high-speed aircraft, missiles, and space craft.

A jointly funded research and development program between the United States and British air forces emphasizing the use of beryllium in aircraft hardware was announced.

A large amount of research on the quality, properties, shaping, fabrication, alloying, and potential uses of beryllium was under way.[6] The brittleness of beryllium continued to be of concern and was studied intensely.[7]

Progress was made in the development of new metalworking techniques for beryllium. The isopressing of complicated shapes as well as the successful rolling of cast beryllium ingot direct to sheet and foil were reported.

The Bureau of Mines continued its comprehensive program on beryllium consisting of studies on the potential domestic beryllium resources and research on the beneficiation of beryllium minerals from low-grade ores, extraction of beryllium compounds from various concentrate and also from ore, reduction of beryllium oxide and chloride to beryllium metal, and electrowinning, melting, casting, and forming beryllium. Numerous occurrences of beryllium mineralization in the northern Virgin Mountains of Nevada and Arizona were reported.[8] Tuff from the Honeycomb Hills area, Juab County, Utah, 20 miles east of Spor Mountain, contains beta-Be(OH) and an amorphous berylliferous substance.[9] In studies on mineral dressing, three samples of bertrandite and phenacite ore from Mount Wheeler, Nev., containing 0.47, 0.78, and 4.7 percent BeO respectively yielded concentrates containing 12.2, 21, and 25 percent BeO; the respective beryllium recoveries were 75.3, 78.3, and 88.5 percent.[10] Pilot plant experiments, indicated that a 500–tons-per-day flotation plant designed to treat tailing (containing 0.066 percent BeO and 0.43 percent Li_2O) from the flotation of spodumene from Kings Mountain, N.C., pegmatites could yield 4 tons of low-grade beryl concentrate containing 6.42 percent BeO, 18 tons of spodumene concentrate containing 5.9 percent Li_2O, and 172 tons of 98-percent pure feldspar concentrate; the direct operating cost for such a plant was estimated at $1.52 per ton of tailing treated.[11] Acid leaching and solvent extraction appeared to be feasible procedure for recovering beryllium from Spor Mountain, Utah, tuff.[12] The design, operation, and some operating costs of a prototype cell for electrorefining beryllium scrap to flake were reported.[13] Electrorefined flake produced from scrap beryllium yielded higher-purity beryllium flake.[14]

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[6] Materials Advisory Board. First Progress Report by the Committee on Beryllium Metallurgy of the Materials Advisory Board. Nat. Acad. Sci. Nat. Res. Council, MAB–199–M(1), June 16, 1964, 46 pp.

Materials Advisory Board. Second Progress Report by the Committee on Beryllium Metallurgy of the Materials Advisory Board. Nat. Acad. Sci. Nat. Res. Council, MAB–199–M(2), Aug. 27, 1964, 82 pp.

[7] Jacobson, Dr. M. I., Lockheed Missiles and Space Co. Beryllium Research and Development Program: Metallurgical Factors Affecting the Ductile-Brittle Transition in Beryllium. Wright-Patterson Air Force Base, Ohio, ASD–TDR–62–509, v. 5, July 1964, 74 pp.

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[8] Holmes, Jr., George H. Investigation of Beryllium Deposits in Northern Virgin Mountains of Clark County, Nev., and Mohave County, Ariz. BuMines Rept. of Inv. 6572, 1964, 30 pp.

[9] Montoya, J. W., G. S. Baur, and S. R. Wilson. Mineralogical Investigation of Beryllium-Bearing Tuff, Honeycomb Hills, Juab County, Utah. BuMines Rept. of Inv. 6408, 1964, 11 pp.

[10] Havens, Richard, and William I. Nissen. Laboratory Continuous Flotation of Bertrandite and Phenacite from Mount Wheeler, Nev., Beryllium Ores. BuMines Rept. of Inv. 6386, 1964, 18 pp.

[11] Browning, James S., Thomas L. McVay, and Paul E. Bennett. Continuous Flotation of Beryl from Spodumene Mill Tailing, Foote Mineral Company, Kings Mountain, N.C., BuMines Rept. of Inv. 6466, 1964, 24 pp.

[12] Dannenberg, R. O., Laird Crocker, and D. W. Bridges. Expanded Investigation of Beryllium Solvent Extraction of Spor Mountain, Utah, Ore. BuMines Rept. of Inv. 6469, 1964, 31 pp.

[13] Wong, M. M., and J. E. Klosterman. Electrorefining Beryllium, Operation of a Prototype Cell. BuMines Rept. of Inv. 6489, 1964, 17 pp.

[14] Wong, M. M., and D. A. O'Keefe. Electrorefined Beryllium, Two-Cycle Electrolysis. BuMines Rept. of Inv. 6570, 1964, 8 pp.

Observations of igneous rocks indicated that beryllium increased with increases of silica, but maximum beryllium content was reached before silica reached its maximum limit.[15] The crystal chemistry of numerous beryllium minerals was studied.[16] Numerous patents on beryllium were issued.[17]

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[15] Shawe, Daniel R., and Stanley Bernold. Distribution of Beryllium in Igneous Rocks. U.S. Geol. Survey Res. Prof. Paper 501–B, 1964, pp B100–B104.

[16] Ross, Malcomb. Crystal Chemistry of Beryllium. U.S. Geol. Survey Prof. Paper 468, 1964, 30 pp.

[17] Bach, Ricardo O. (assigned to Beryllium Metals & Chemicals Corp.). Production of Beryllium Chloride from Beryl Ore. U.S. Pat. 3,146,065, Aug. 25, 1964.

Bach, Ricardo O. Process for Producing Beryllium Chloride From Beryllium Oxide Material. U.S. Pat. 3,146,066, Aug. 25, 1964.

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Smith, Ellsworth M. (assigned to The Brush Beryllium Co.). Beryllium-Bronze Alloy. U.S. Pat. 3,150,969, Sept. 29, 1964.

Surls, Jr., Joseph P., Charles W. Becker, and William A. Mod (assigned to The Dow Chemical Co.). Recovery of Beryllium Values. U.S. Pat. 3,131,994, May 5, 1964.

Surls, Jr., Joseph P., and Robert R. Grinstead (assigned to The Dow Chemical Co.). Process for Concentration and Purification of Beryllium Values. U.S. Pat. 3,145,081, Aug. 18, 1964.

Bismuth

By Donald E. Moulds[1]

◆

PRODUCTION AND CONSUMPTION of refined bismuth at domestic plants declined in 1964 in comparison with 1963. Producer shipments were substantially above production, and producer stocks were reduced. Imports of bismuth metal increased slightly, as did exports of metal and alloys, and consumer-dealer stocks at yearend were increased substantially. The quoted price of refined bismuth rose 10 cents to $2.35 per pound on July 10, the first movement in price since September 1950. The Government did not acquire bismuth during the year.

World production of bismuth during 1964 was estimated at 7.2 million pounds, approximately 6 percent above the 1963 total. The larger supply of bismuth resulted primarily from substantially higher base-metal output and improved bismuth recovery in Peru, Mexico, and the Republic of Korea.

TABLE 1.—Salient bismuth statistics

(Pounds)

	1955–59 (average)	1960	1961	1962	1963	1964
United States:						
Consumption	1,503,380	1,527,252	1,478,423	1,909,548	2,175,038	2,160,100
Imports, general	691,212	1,167,019	798,518	816,190	1,123,466	1,238,252
Exports	229,043	156,636	167,166	118,056	32,293	47,958
Price: New York, average ton lots	$2.25	$2.25	$2.25	$2.25	$2.25	$2.30
Stocks Dec. 31: Consumer and dealer	371,300	362,800	323,000	447,800	428,100	656,900
World: Production	4,800,000	5,300,000	5,600,000	6,700,000	6,800,000	7,200,000

DOMESTIC PRODUCTION

Bismuth was essentially produced as a lead refinery byproduct derived from foreign and domestic base-metal ores. Secondary bismuth, derived from reclaimed bismuth alloys, provided an additional supply, usually reprocessed in the form of alloys. Companies reporting primary production of refined metal in 1964 were American Smelting and Refining Company, with refining plants at Omaha, Nebr., and Perth Amboy, N.J., and United States Smelting Lead Refinery, Inc., at the refinery in East Chicago, Ind. The Anaconda Company produced a bismuth intermediate smelter product which was refined by American Smelting and Refining Company, and, United Refining & Smelting Co., East Chicago, Ind., produced bismuth primarily from secondary materials. Production from primary sources declined for the second successive year, and secondary production also declined with total production of domestically refined bismuth approximately 10.5 percent below that of 1963. Shipments were, however, substantially above production for the year, and producer stocks at yearend were about 21 percent lower than in 1963.

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[1] Commodity specialist, Division of Minerals.

CONSUMPTION AND USES

Consumption of refined bismuth metal declined to 2.16 million pounds in 1964, some 15,000 pounds less than the record consumption of 2.18 million pounds in 1963. Requirements for fusible alloys and pharmaceuticals decreased, but requirements for the classifications "other alloys," "experimental uses," and "other uses" increased.

The leading use classification continued to be pharmaceuticals, which includes the bismuth consumed in medicines, cosmetics, and chemicals. Of the 757,000 pounds reported for this category, about 54 percent was consumed in manufacturing industrial chemicals and in chemical laboratories. A major use in this field is as an oxidation catalyst in the formation of acrylonitrile, the raw material for the manufacture of acrylic fiber.

Bismuth metal used for the manufacture of bismuth alloys, other than fusible alloys, continued the upward trend initiated in 1962; consumption has tripled since 1961. This category covers bismuth in alloys of significant bismuth content and bismuth used as a minor additive to aluminum, malleable and ductile iron, and certain alloy steels. Bismuth requirements for these metallurgical uses as reported to the Bureau of Mines totaled about 586,000 pounds. Requirements for fusible alloys declined for the second successive year from the record 796,000 pounds used in 1962. Direct use of bismuth-lead bullion in fusible alloys, decreased 24 percent from that used in 1963.

TABLE 2.—Bismuth metal consumed in the United States, by uses

(Pounds)

Use	1963	1964	Use	1963	1964
Fusible alloys	[1] 763,862	[1] 688,255	Experimental uses	6,433	18,551
Other alloys	572,543	668,659	Other uses	23,817	27,771
Pharmaceuticals [2]	808,383	756,864	Total	2,175,038	2,160,100

[1] Includes 168,137 pounds of bismuth contained in bismuth-lead bullion used directly in the production of an end product in 1963 and 127,446 pounds in 1964.

[2] Includes industrial and laboratory chemicals.

STOCKS

Consumer and dealer stocks of refined bismuth increased from 428,000 pounds at the beginning of the year to 657,000 pounds at yearend. This is the largest stock reported since publication was initiated in the 1953 Minerals Yearbook. Producer stocks declined during the year as shipments substantially exceeded production.

Government stockpiles contained 3.8 million pounds of refined bismuth, unchanged during the year in amount or distribution in the various inventories. Of the total, the strategic stockpile held 1.3 million pounds; the supplemental stockpile, 2.5 million pounds; and the Defense Production Act inventory, 23,000 pounds. Approximately 235,000 pounds was surplus to the stockpile objective. An additional 37,000 pound inventory of non-stockpile-grade bismuth is not included in the surplus.

PRICES

The price of refined bismuth as quoted by the E&MJ Metal and Mineral Market (New York) was increased 10 cents per pound on July 10, the first change in quoted price since September 1950. The resulting $2.35 per pound was still quoted at yearend.

Prices of bismuth alloys were adjusted upward from 4 to 11 percent, effective July 20, to reflect the revised price of the bismuth content.

The price of bismuth metal in London, in ton lots, exwarehouse, as quoted in the Metal Bulletin (London), continued at $2.25 per pound (U.S. equivalent) until July 10, when the price advanced to $2.38. The London price of bismuth ore was unchanged at $1.19 per pound of contained bismuth in 65-percent bismuth material with related prices for lower grade materials until revised to "nominal" on July 10.

FOREIGN TRADE

General imports of refined bismuth were 10 percent more than in 1963 as receipts from Peru increased 20 percent, and those from Mexico, 47 percent. Shipments from Canada and Europe were much lower than in 1963.

Bismuth was also imported in base-metal concentrates, base-metal bullion, and intermediate smelter products for processing in domestic smelters and lead refineries and marketing as refined bismuth. Approximately 127,400 pounds of bismuth contained in bismuth-lead bullion was imported and consumed directly as an alloy in the manufacture of end products.

Exports of bismuth metal and alloys increased 49 percent to 48,000 pounds gross weight. The Netherlands received 46 percent; the United Kingdom, 28 percent; and Canada, 18 percent. The remaining 8 percent was distributed to eight free world countries. Approximately 13,300 pounds of bismuth-bearing intermediate smelter products were exported to the Netherlands, Canada, and the United Kingdom.

TABLE 3.—U.S. general imports of metallic bismuth, by countries

(Pounds)

Country	1963	1964
North America:		
Canada	152,408	80,671
Mexico	166,322	244,709
Total	318,730	325,380
South America: Peru	728,909	877,180
Europe:		
Germany, West		5
Netherlands	18,513	4,310
United Kingdom	3	
Yugoslavia	57,311	31,377
Total	75,827	35,692
Grand total	1,123,466	1,238,252

Source: Bureau of the Census.

TABLE 4.—U.S. exports of bismuth metal and alloys

Year	Gross weight (pounds)	Value
1955-59 (average)	229,043	$357,109
1960	156,636	275,540
1961	167,166	267,775
1962	118,056	$176,163
1963	32,293	42,271
1964	47,958	76,801

Source: Bureau of the Census.

WORLD REVIEW

The estimated world production of 7.2 million pounds of bismuth is almost 6 percent above the revised total of 6.8 million pounds for 1963. The major producers were Bolivia, Canada, Japan, Mexico, Peru, South Korea, and the United States. Significant increases in output occurred in Mexico, Peru, and South Korea, continuing the upward trend of previous years, whereas the downward trend in output continued in Bolivia and Yugoslavia.

Bolivia.—The production of bismuth, as a byproduct of smelting certain tin ores, declined again in 1964. Bismuth contained in the increased export of tin concentrate and recovered at European and U.S. smelters is not included in the estimated total.

Canada.—Three companies—Consolidated Mining and Smelting Company of Canada, Ltd.; Molybdenite Corporation of Canada, Ltd.; and Gaspé Copper Mines, Ltd.—produced essentially all of the Canadian bismuth. Consolidated Mining and Smelting Company produced a lead bullion at the Trail, British Columbia, smelter, containing about 0.05 percent bismuth which is segregated in the electrolytic lead refinery and refined to 99.99+ percent bismuth metal. Molybdenite Corporation produced a molybdenite-bismuth ore at the Lacorne mine, northwest of Val d'Or, Quebec, from which a bulk concentrate, averaging 8 percent bismuth, was obtained and reduced by leaching and electric furnace smelting to an impure (98 percent) bismuth bullion. Gaspé Copper Mines, Ltd., recovered bismuth in treating flue dust from the copper smelter at Murdochville, Quebec. A small amount of bismuth was recovered at the silver refinery of Cobalt Refinery, Ltd., Cobalt, Ontario, and shipped to a lead smelter for further refining.

TABLE 5.—World production of bismuth, by countries [1] [2]

(Pounds)

Country [1]	1955-59 (average)	1960	1961	1962	1963	1964
North America:						
Canada (metal) [3]	323,845	423,827	478,118	425,102	359,125	387,213
Mexico [3]	778,136	599,400	643,700	780,000	941,400	[e] 1,058,000
South America:						
Argentina (in ore)	[e] 34,200	[e] 14,900	[e] 8,600	7,100	7,600	[e] 7,500
Bolivia [4]	202,110	403,700	465,300	652,500	617,300	[e] 573,200
Peru [3]	752,690	908,438	1,031,795	1,084,227	1,243,070	[e] 1,635,800
Europe:						
France (in ore)	98,980	112,400	116,800	138,890	[e] 110,000	[e] 110,000
Spain (metal)	95,951	29,875	21,427	18,799	25,836	[e] 25,800
Sweden [e]	106,300	79,000	79,000	155,000	155,000	155,000
Yugoslavia (metal)	212,810	231,582	216,348	199,765	194,657	[e] 178,600
Asia:						
China (in ore)	[e] 420,000	(6)	(6)	(6)	(6)	(6)
Japan (metal)	167,197	261,089	422,326	572,841	823,314	[e] 823,000
Korea, South (in ore)	269,800	317,000	333,000	353,000	349,000	[e] 440,000
Africa:						
Mozambique	7,443	29,983	38,800	13,889	24,317	[e] 24,300
South Africa, Republic of (in ore)	657	511	168	130	2,529	[e] 220
South-West Africa (in ore)	906	309	485	154	5,115	[e] 4,850
Uganda	8,120	3,638	1,433	110	65	[e] 65
Oceania: Australia (in ore)	2,515	265	602	[5] 97	----------	----------
World total (estimate) [1] [2]	4,800,000	5,300,000	5,600,000	6,700,000	6,800,000	7,200,000

[e] Estimate.

[1] United States figure withheld to avoid disclosing individual company confidential data; included in world total. Bismuth is believed to be produced in Brazil, East and West Germany, and U.S.S.R. Production figures are not available for these countries, but estimates are included in the world total.

[2] This table incorporates some revisions. Data do not add exactly to totals shown because of rounding where estimated figures are included in the detail.

[3] Bismuth content of refined metal and bullion plus recoverable content of concentrates exported.

[4] Content in ore and bullion exported, excluding that in tin concentrates.

[5] Exports.

[6] Data not available; estimate included in world total.

Development of molybdenite-bismuth deposit of significant size in northwest Quebec by Anglo American Molybdenite Mining Corp. was initiated in January 1964, with production scheduled to start in September 1965.

Japan.—Production of bismuth as a byproduct of smelting domestic and foreign base-metal concentrates was approximately the same as in 1963, a record year for base-metal production.

Korea, South.—The entire output of bismuth was recovered as a byproduct in processing tungsten ore and concentrate from the Sangdong mine. Korea Tungsten Mining Co. operated a bismuth refinery in conjunction with the tungsten beneficiation plant and produced refined bismuth metal.

Mexico.—Refined bismuth metal was produced by Metallurgica Mexicana Peñoles, S.A., and bismuth-lead bullion and drosses were produced at the Monterrey lead smelter of Compania Minera Asarko, S.A. The impure bismuth products were exported to the United States for refining. The upward trend in production that began in 1961 continued in 1964.

Peru.—Output of bismuth at the La Oroya refinery complex of Cerro de Pasco Corp. continued at a high level as production of base-metal continued to reflect plant improvements and uninterrupted operations. The United States imported approximately one-half of the production of bismuth as bismuth-lead bars, as refined metal, and contained in lead concentrate; the remainder was consigned principally to Norway and the United Kingdom, and small amounts went to other destinations.

United Kingdom.—A smelter and refinery, with a monthly capacity of 150,000 pounds of refined bismuth, was operated by Mining and Chemical Products, Ltd., at Alperton, Middlesex. Bismuth materials from Bolivia, Australia, Africa, and Canada were processed.

Yugoslavia.—Bismuth metal production at Zvecan Lead Smelter & Refinery of the Trepca mining and refining complex decreased again in 1964. The Novo Brdo mine, reopened in 1964, was expected to supply a substantial tonnage of lead-zinc ore containing a significant amount of bismuth to supplement current sources of bismuth for the Trepca operations.

TECHNOLOGY

Technological and industrial advancement in bismuth continued over a wide range of applied research. Of special significance were developments in the use of bismuth as an oxidation catalyst in the formation of acrylonitrile, the raw material for manufacture of acrylic fiber.[2] Commercial acceptance of this process indicates an increasing consumption of bismuth.

The importance of bismuth oxide in the ceramic and electronics industry has resulted in increased research in structural and transformation characteristics of polymorphism and phase equilibrium relationships.[3] The electronics industry continued searching for new and improved applications of ultra-high-purity bismuth. Research was reported on methods and techniques of growth of bismuth single crystals[4] and on electromagnetic characteristics of bismuth doped with tellurium or tin.[5]

The characteristics imparted to aluminum, steel, and malleable iron by adding metallic bismuth to the melt continued to receive metallurgical study. Bismuth was reported to have beneficial effects on structure and properties of malleable iron.[6]

The problems and methods of chemical analysis of concentrates containing bismuth were described,[7] and the Bureau of Mines initiated a project to develop improved methods for recovering bismuth from ores and intermediate smelter products.

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[5] Schultz, B. H., and J. M. Noothoven van Goor. Hall Effect and Resistivity of Bismuth Doped With Tellurium or Tin. Philips Technical Review (Eindhoven, the Netherlands), v. 19, No. 2, April 1964, pp. 103–111.

[6] Loper, Carl R., Jr., P. S. Nagarsketh, and R. W. Heine. Processing Is Key to—Ductile Iron Quality. Foundry, v. 92, No. 10, October 1964, pp. 65–69.

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Boron

By William C. Miller[1]

◆

ANTICIPATED increases in domestic consumption and export demand for boron compounds were reflected in the announced plans for the expansion of production facilities. Plans were released for plant expansion by two basic producers, construction of two new plants by chemical companies, and the resumption of operation by a manufacturing firm of a plant that was on a standby basis.

Exports of boron and compounds accounted for almost half of the domestic production. Over 60 percent of the exports were shipped to European countries.

Significant advancements were achieved in research and development of boron polymers, epoxy-boron fibers, and organoboron compounds.

TABLE 1.—Salient boron minerals and compounds statistics in the United States

	1955-59 (average)	1960	1961	1962	1963	1964
Sold or used by producers:						
Short tons:						
Gross weight	551,169	640,591	602,613	646,613	700,183	776,279
Boron oxide	272,648	323,955	313,104	339,060	369,302	404,975
Value thousands	$37,208	$47,550	$46,936	$49,336	$54,981	$60,871
Imports for consumption:						
Short tons	[1] 1,077	74	15	15	17	[1] 47
Value thousands	$158	$202	$52	$51	$58	$21
Exports:						
Short tons	234,014	300,606	269,271	292,264	338,912	383,100
Value thousands	$17,289	$25,576	$23,212	$24,736	$27,519	$31,289
Consumption, apparent:						
Short tons	318,232	340,059	333,357	354,364	361,288	393,226

[1] Imports for 1956, 1957, and 1964 include a higher proportion of crude ore to refined products.

DOMESTIC PRODUCTION

A high rate of industrial activity in the major market areas of boron products accounted for the increase in the production of boron minerals and compounds by primary producers. The production as measured by sales increased 11 percent in quantity and value, and 10 percent in the boron oxide content compared with 1963. All primary boron products except decahydrate borax showed increases.

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[1] Commodity specialist, Division of Minerals.

Borax and kernite mined at the open-pit operation near Boron, Calif., of the United States Borax & Chemical Corp., supplied the bulk of the production of boron minerals and compounds. Borate-rich brines of Searles Lake were used for the production of boron minerals and compounds by the American Potash & Chemical Corp., Trona, Calif., and West End Division of Stauffer Chemical Co., Westend, Calif., second and third major producers, respectively. Colemanite was mined in Inyo County, Calif., by the Kern County Land Co. at the Kern Borate Mine and by United States Borax & Chemical Corp. at the DeBely mine. Ulexite was mined at the Gerstley mine, Inco County, Calif., by U.S. Borax.

Boron compounds were produced at the refineries operated by U.S. Borax at Boron and Wilmington, Calif., the American Potash & Chemical Co. plant at Trona, and the refinery operated by Stauffer Chemical Co. at San Francisco, Calif.

Stauffer Chemical Co. disclosed plans to increase by 50 percent the borax capacity of its Westend, Calif., plant. A new process, proven in pilot operation, was included in the expansion progam to produce an estimated 92,000 tons a year. U.S. Borax announced plans to expand by 30 percent the anhydrous borax capacity of its Boron, Calif., plant. An increase in the production to 165,000 tons a year was estimated by the installation of an additional 100-ton-a-day borax fusing furnace. The company converted the earth-moving operations of its open-pit mine at Boron from a scraper-tractor method to a shovel-truck stripping system.

The U.S. Atomic Energy Commission (AEC) negotiated a contract with Nuclear Materials & Equipment Corp., Apollo, Pa., to produce boron 10 at the AEC's boron production plant, Model City, N.Y.

An agreement was completed between U.S. Borax and Hooker Chemical Corp. for a new plant built by U.S. Borax on the Hooker property at Columbus, Miss., for the production of boron-based herbicides. An industrial building at the Edgewood Arsenal near Annapolis, Md., was leased by a newly formed company, Humphrey Chemical Corp., for the manufacture of zinc borate.

CONSUMPTION AND USES

Of the boron minerals and compounds produced in the United States, domestic consumption utilized 51 percent and export markets utilized 49 percent. The major domestic consumers of borates were the fiber-glass, borosilicate glass, and porcelain enamel producers. Sizable amounts of boron compounds were consumed in soaps and cleaners, herbicides, fertilizers, catalysts and precursors for other materials, antifreezes, and fire retardants. Borax and borates were used by the adhesive, insulation, cosmetic, drug, iron and steel, nonferrous metal refining, textile, and leather industries. Boron 10 was used in the manufacture of neutron-absorbing materials and protective radiation shields.

Boron was consumed in the 348,085 short tons of alloy steel (other than stainless steel) ingots produced in 1963, compared with 282,085 tons produced in 1962.[2]

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[2] American Iron & Steel Institute. Annual Statistical Report. New York, 1963, p. 54.

Most of the developments during 1964 for the use of boron and its compounds were new applications and improved products rather than the manufacture of new compounds. Several boron-coating materials were made available. Two neutron-absorbing powders, crystalline boron and hexaboron silicide, applied with plasma spray equipment were placed on the market. They were reported to produce coatings with excellent bonding and heat-resistance properties and relatively low porosity; they also formed self-healing oxide films in oxidizing atmospheres. An abradable coating with good oxidation resistance at high temperatures and suitable for gas turbine engines was produced by combining boron nitride with nickel chromium.

Two moistureproof compounds were made available: A waterproofing agent containing boron and silicon esters was developed for concrete surfaces and a moistureproof grade of boron nitride was produced for dielectric applications in the electronic and aerospace industries.

Other boron compounds placed on the market during the year included an alkyl borate used to prevent the formation of scale on reheated steel. Compounds composed of boron fibers and epoxy were used in self-lubricating, lightweight and extremely strong bearings for shafts of vertical takeoff aircraft. An especially designed line of polyethylene-boron bricks to shield against high thermal neutron fluxes were made available. A 12-percent boride solution in caustic was placed on the market for woodpulp bleaching. Transistor mounting wafers made of boron nitride were made available.

The addition of boron or its compounds to certain manufacturing processes was reported to improve the end product or the operations. Boron added during the deoxidation of semikilled low carbon steels tended to stabilize the deep drawing properties of the steel. The addition of boron and increased molybdenum content improved the high temperature strength of type 422 stainless steel. Boron compounds used in combination with lead and calcium in polyvinyl chloride mixtures achieved high thermal stabilization of the polyvinyl chloride. The use of sodium-borohydride-based compounds improved the stability, lowered the costs, and provided greater control of dry operations in the vat coloring of textiles. Improvements in the cure and extension of the pot life of epoxy resins were achieved by the use of organoboron compounds.

PRICES

The following prices quoted for borax and boric acid by the Oil, Paint and Drug Reporter remained constant during 1964.

Compound:	*Per ton*
Borax, technical:	
Anhydrous, 99 percent:	
Bags, carlots, works	$92.00
Bulk, carlots, works	83.00
Granular, decahydrate 99.5 percent:	
Bags, carlots, works	50.00
Bulk, carlots, works	43.50
Granular, pentahydrate 99.5 percent:	
Bags, carlots, works	64.50
Bulk, carlots, works	58.00

	Per ton
Compound—Continued	
Boric acid, technical:	
Anhydrous 99.9 percent; bags, carlots, works	$335.00
Crystals, 99.9 percent:	
Bags, carlots, works	168.50
Drums, carlots, works	193.50
Granular 99.9 percent	
Bags, carlots, works	112.00
Drums, carlots, works	137.00
Bulk, carlots, works	106.00
Boric acid, U.S.P., in bags, $25 per ton higher than technical.	
Sodium borate, U.S.P., powder, bags, carlots, works	54.00

FOREIGN TRADE

Imports.—Crude sodium and calcium borates imported from Spain and Turkey totaled 44 tons valued at $1,876. Imports of boron carbide from West Germany and Canada were 4,845 pounds valued at $19,357, compared with 13,468 pounds valued at $39,398 in 1963. Ferroboron and alloys of boron were not separately classified.

Exports.—A change in the method of shipping borate products to Europe resulted in fewer direct exports to several countries but in greatly increased exports to the Netherlands. Before 1964, borate products were shipped only in packages directly to the various countries. In 1964, bulk-handling facilities at Los Angeles and at Rotterdam, Netherlands, were put into full operation and shiploads of bulk borate products were regularly dispatched. The products were distributed in continental Europe and the United Kingdom.

TABLE 2.—U.S. exports of boric acid, borates, and compounds [1]

Destination	1963		1964	
	Short tons	Value	Short tons	Value
North America:				
Canada	19,224	$1,991,711	19,897	$2,000,937
Costa Rica	705	68,737	654	62,635
Dominican Republic	80	23,218	32	4,811
Mexico	7,834	763,503	9,278	939,140
Nicaragua	28	6,630	23	6,079
Other	87	14,616	125	20,872
Total	27,958	2,868,415	30,009	3,034,474
South America:				
Brazil	4,822	512,997	3,887	428,781
Colombia	1,442	152,888	747	77,195
Peru	490	43,665	469	42,559
Uruguay	260	27,683	269	31,204
Venezuela	207	22,440	351	43,861
Other	16	2,301	61	6,851
Total	7,237	761,974	5,784	630,451
Europe:				
Austria	3,938	206,073	678	37,057
Belgium-Luxembourg	5,875	573,611	5,344	503,859
Denmark	1,122	79,459	1,029	90,642
Finland	2,329	184,196	1,511	128,194
France	42,878	3,395,257	29,681	2,822,664
Germany, West	64,125	4,259,049	28,377	2,478,171
Greece	159	14,967	347	17,072
Ireland	1,390	84,934	875	61,574
Italy	9,828	812,046	8,432	823,985
Netherlands	35,183	2,561,863	139,246	8,462,192
Norway	2,775	215,269	1,891	138,785
Portugal	1,145	85,288	1,311	98,655
Spain	4,096	158,625	1,972	148,529
Sweden	3,960	334,828	4,012	371,765
Switzerland	3,315	290,538	4,004	361,669
United Kingdom	50,117	3,943,554	30,439	2,931,943
Yugoslavia	1,197	113,653	2,304	219,252
Other	(2)	274	----	----
Total	233,432	17,313,484	261,453	19,696,008
Asia:				
Ceylon	235	$18,338	363	$23,637
Hong Kong	3,990	356,071	4,217	402,186
India	7,153	585,290	15,693	1,225,962
Indonesia	582	38,068	301	20,833
Iran	268	24,513	243	17,143
Israel	669	71,053	846	70,804
Japan	34,707	3,179,189	37,246	3,379,068
Korea, South	627	51,054	740	54,383
Malaysia	717	55,371	579	50,008
Pakistan	645	52,355	1,716	137,295
Philippines	1,258	119,990	932	102,811
Taiwan	1,252	79,845	1,890	125,335
Thailand	652	65,002	600	56,448
Viet-Nam	682	132,473	1,311	298,261
Other	147	24,648	155	13,062
Total	53,584	4,853,260	66,832	5,977,236
Africa:				
Rhodesia and Malawi	509	40,191	673	52,094
South Africa, Republic of	2,409	255,512	3,296	396,880
United Arab Republic (Egypt)	252	21,199	347	26,200
Other	370	59,335	250	33,290
Total	3,540	376,237	4,566	508,464
Oceania:				
Australia	8,870	831,607	9,495	856,721
New Zealand	4,208	502,154	4,799	571,986
Other	83	11,671	162	13,664
Total	13,161	1,345,432	14,456	1,442,371
Grand total	338,912	27,518,802	383,100	31,289,004

[1] Classified by the Bureau of the Census as boric acid and borates, crude, refined, and compounds (including borate esters and other boron compounds) not elsewhere classified.

[2] Less than ½ unit.

Source: Bureau of the Census.

WORLD REVIEW

Production of borax in Argentina and exports of colemanite ores from Turkey showed substantial increases in 1964. Most of the borax exported from Argentina was shipped to other South American countries. The colemanite exports from Turkey went primarily to borate plants in France, West Germany, and Italy.

Production facilities and construction of new plants increased in several countries to supply the increasing demand for boron compounds.

SOUTH AMERICA

Argentina.—Two firms produced borax in the Provinces of Salta and Jujuy. The larger producer, Boroquímica Ltda. completed a program to increase its output by 50 percent. The increased facilities raised the annual production capacity to 20,000 tons, which included both granular (10 mole) and anhydrous borax. Production by this company in 1964 amounted to 13,224 tons, or approximately 70 percent of the total for the country. Exports in 1964 totaled 8,932 tons valued at $834,000, compared with 5,963 tons valued at $512,000 in 1963. Most of the exports were shipped to Brazil.

Chile.—Borax Consolidated, Ltd., the only producer of boron minerals in Chile, operated a mine in Antofagasta Province near the Bolivian border. Difficulties in obtaining laborers resulted in a decrease in the production of upgraded ulexite, 33 percent boron oxide content, from 4,203 tons in 1962 to 3,285 tons in 1963.[3]

EUROPE

Italy.—Boric acid produced in 1963 from steam vents amounted to 573 tons valued at $94,400.

Spain.—Changes of duty on imports into Spain were as follows:

Description of borates:	*Final duty, percent*
Hydrated borax	30
Anhydrous borax	45
Other borates	1

ASIA

India.—A new company, Borax Morarji Ltd., a joint venture between Borax (Holdings) Ltd. of London and Dharamis Morarji Chemical Co., Ltd., of Bombay, was formed for the manufacture of boron products.

Japan.—Plans for the manufacture of boron trifluoride, for the first time in Japan, was announced by Hashimoto Chemicals Industries Co.

Turkey.—Production of boron minerals, primarily colemanite, increased to 141,336 tons valued at $3,033,000 in 1964, compared with 97,073 tons valued at $2,405,000 in 1963. Exports increased from 100,877 tons valued at $2,681,000 in 1963 to 130,486 tons valued at $3,303,000 in 1964.

The minimum export price for colemanite ores established in 1964 by the Turkish Mining Association was $24 per metric ton, f.o.b. Turkish port, compared with a minimum of $30 per ton prevailing in 1961.[4] Export prices in 1964 ranged from $24.30 per ton for crude ore to $34.70 per ton for washed, hand-sorted ore. The average value of all exported colemanite ore was $27.89 per ton.

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[3] Bureau of Mines. Mineral Trade Notes. V. 59, No. 2, August 1964, p. 8.

Etibank management reported that work had started on the site preparation for a boron-processing plant with an annual capacity of 5,000 tons of boric acid and 20,000 tons of borax.

TECHNOLOGY

The results were reported on a program to evaluate existing methods for the preparation of high-purity elemental boron and to study new preparative methods. In each method the principal obstacle was the contamination of the boron product. Two feasible processes for producing high-purity elemental boron on a large scale were demonstrated. One method involved magnesium reduction of boron trioxide by thermite reaction and the other by the electrolysis of certain fused-salt baths containing boron compounds.[5]

A study was made of the corrosion resistance of diborides in the pseudobinary system TiB_2-CrB_2. Tests were made to determine the resistance to molten metals, to oxidation at elevated temperatures, and to corrosion by various chemical reagents.[6]

Additional information was disclosed on the chelating agents developed by the American Potash & Chemical Co. for its boron extraction process. The preferred chelating agent was 2-chlor-4-(1,1,3,3-tetramethylbutyl)-6-methylophenol. More than 25 compounds were investigated in the development study.[7]

A study was made to obtain the formation conditions and properties of boron phosphides (BP and $B_{13}P_2$). The methods of preparation, the boron-phosphorus reactions, zinc phosphide-amorphous boron reactions, growth of large $B_{13}P_2$ crystals and chemical analysis of $B_{13}P_2$ were discussed. The properties of BP and $B_{13}P_2$ were compared. Methods for fabricating dense refractory bodies were presented. Test results indicated that $B_{13}P_2$ was useful in polishing hard materials and may have potential applications in nuclear or missile fields as a cutting tool and as wear-resistant parts or coatings.[8]

Research results of a test program indicated that boron trichloride (BCl_3) is an active catalyst and provides a large yield for converting unsaturated hydrocarbons into resins. A resin with a high softening point was obtained, which was particularly suitable as a binder ingredient in floor tiles.[9]

A research report was published on the plasma torch production of elemental boron. A method was described for preparing elemental boron by hydrogen reduction of boron trifluoride (BF_3) and boron trichlorides (BCl_3) in a plasma system. The maximum yield obtained was 60 percent with BCl_3. The chemical purity of the boron produced with BCl_3 was 99.1 percent.[10]

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[4] Bureau of Mines. Mineral Trade Notes. V. 58, No. 5, May 1964, pp. 9–10.

[5] Hobbs, D. Z., T. T. Campbell, and F. E. Block. Methods Used in Preparing Boron. BuMines Rept. of Inv. 6456, 1964, 16 pp.

[6] Farrior, Gilbert M. Corrosion Resistance of Diborides in the Pseudobinary System TiB_2-CrB_2. BuMines Rept. of Inv. 6418, 1964, 21 pp.

[7] Chemical & Engineering News. Patent Tells More About Boron Extractants. V. 42, No. 3, Jan. 20, 1964, pp. 41–42.

[8] Peret, James L. Preparation and Properties of the Boron Phosphides. J. Am. Ceram. Soc., v. 47, No. 1, January 1964, pp. 44–46.

[9] Chemical Engineering. Boron Trichloride Catalysis Makes Resins With High Softening Points. V. 71, No. 3, Feb. 3, 1964, pp. 31, 34.

Methods for the preparation of high-purity boron were investigated. The emphasis of the research was on the use of boron triiodide as the intermediate. The most satisfactory method for preparing boron triiodide was the direct combination of the elements. A distillation procedure gave the best results of the several methods investigated for the purification of boron triiodide. The purity of the resulting iodide boron and of the best available bromide boron are about the same.[11]

Research programs by the major manufacturers of glass fibers were concentrated on developing new glass compositions with higher tensile strength, modulus, and heat resistance. A high-boron borosilicate glass was developed that has an exceptionally low dielectric constant. Hollow glass fibers have been developed that are more rigid and have better electrical properties and lower thermal transmission.[12]

The recovery of boron from scrap boron 10 materials by a technique called pyrohydrolysis was announced by AEC. Elemental boron, carbide, and boride were converted to oxides in a nickel reaction tube. Steam at 1,742° F distilled the oxide as boric acid which was treated with potassium hydroxide and hydrofluoric acid to form potassium tetrafluoroborate.[13]

A moistureproof grade of boron nitride was developed. It was especially useful for the electronics and aerospace industries because of low water absorption and thermal expansion properties.[14]

Results of an investigation using various saturated vapors indicated that there is no correlation between the permanent dipole moment of the atmosphere and the fracture strength of borosilicate glass. A significant fact determined from a comparison of the fracture strengths was that *o*-dichlorobenzene with a dipole moment much larger than water did not change the strength as much as water. The dipole moment and the average fracture strength of borosilicate glass rods in seven saturated vapors were reported. A comparison of the values showed that no relation exists between the fracture strength and the molecular dipole moment.[15]

The tips of metal cutting tools made of alumina ceramics were significantly increased in strength when chemically polished. The best polish for this purpose was produced by a fusion of borax at 1,560° F.[16]

A British patent was issued for a method of hardening the surface of alloy parts. The surfaces were covered with a fine powder that contained at least 8 percent boron by weight and the part was heated in a hydrogen atmosphere above 1,260° F. Satisfactory results were obtained when pure boron, a boron compound, or an alloylike ferroborn was used.[17]

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[10] Biggerstaff, G. E., W. R. Golliher, R. L. Harris, and W. R. Rossmassler. Plasma Torch Production of Elemental Boron. U.S. Dept. of Commerce, Office of Tech. Services, Rept. KY–453, Feb. 26, 1964, 38 pp.

[11] Armington, A. F., G. F. Dillon, and R. F. Mitchell. The Preparation of High-Purity Boron Via the Iodide. Trans. AIME, v. 230 (Metal Soc.), No. 2, March 1964, pp. 350–354.

[12] Chemical Week. Glass Gets Tough. V. 94, No. 15, Apr. 11, 1964, pp. 59–60.

[13] Steel. Process Saves Boron. V. 154, No. 17, Apr. 27, 1964, pp. 19–20.

[14] Steel. New Grade of Boron Nitride Moistureproof. V. 154, No. 22, June 1, 1964, p. 45.

[15] Lunsford, Jack H. Loss in Fracture Strength of Borosilicate Glass in Vapors of Differing Dipole Moments. J. Am. Ceram. Soc., v. 47, No. 6, June 1964, p. 309.

[16] Steel. Ceramic Tool Tip. V. 155, No. 5, Aug. 3, 1964, p. 18.

The procedure used in developing the first member of a new class of carborane compounds and the molecular structure of the member, 1-isopropenylcarborane, were described. Several examples of the scope and broad applicability of the carborane reaction were presented.[18]

Some physical and optical properties and the chemical durability of a zinc borophosphate glass was investigated because of its unusual composition. The melting range of this glass was 1,000° to 1,100° C, a softening point of 579° C, an annealing point of 509° C, and a strain point of 432° C. The glass had an index of refraction at the sodium D-line of 1.686, a very low dispersion or *v* value of 25.5, and appeared optically clear. The resistance of the glass to water attack was quite high but the acid durability was quite low.[19]

An investigation was conducted to develop a practical process for a large-scale industrial operation in the preparation of decaborane ($B_{10}H_{14}$). The process developed was based on the thermal conversion of diborane to decaborane in a closed recycle system with pentaborane formed as an intermediate product. A relatively high constant temperature and constant pressure were used in the operation of the pyrolysis system. Procedure, apparatus, and flow diagram of a process suitable for adaptation to large-scale plant operation were described.[20]

A study was made of infrared spectra of crystalline inorganic borates. Methods used to prepare the borates were described. Anion structure and vibration analysis were discussed. Data on infrared absorption bands for about 80 inorganic borates were reported. Some generalizations on the spectroscopic identification of borate anions were made.[21]

Borohydride was used as a source of hydrogen for a new apparatus to measure precisely unsaturation on an ultramicro scale. By measuring the volume of hydrogen consumed in the catalytic hydrogenation of the material tested, measured concentrations of unsaturation as low as 5×10^{-6} gram mole were made. Hydrogen generated with the apparatus simplified the apparatus and reduced the analysis time.[22]

Heat-resistance tests were conducted involving zirconium diboride-coated tanalum and columbium. Results of these tests showed that the coating raised the heat limits on metal parts. Diboride-coated thermowells used in aluminum production and in basic oxygen furnaces for steelmaking lasted much longer than the thermowells presently used.[23]

The first volume of a series titled "Organaboron Chemistry" covering organoboron compounds was published. The book dealt with compounds containing boron-oxygen or boron-sulfur bonds. An outstanding feature of the book was that all important references through 1961 in this area of chemistry were included.[24]

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[17] Steel. Method Hardens Alloy Part. V. 155, No. 8, Aug. 24, 1964, p. 20.

[18] Bobinski, Jack. The Discovery of a New Class of Compounds: Carboranes. J. Chem. Education, v. 41, No. 9, September 1964, pp. 500–501.

[19] Grossman, D. G., and C. J. Phillips. Zinc Borophosphate Glass. J. Am. Ceram. Soc., v. 47, No. 9, Sept. 21, 1964, p. 471

[20] Polak, R. J., and Clayton Obenland. Pyrolysis of Diborane. Ind. and Eng. Chem. Product Res. and Development, v. 3, No. 3, September 1964, pp. 234–238.

[21] Weir, C. E., and R. A. Schroeder. Infrared Spectra of the Crystalline Inorganic Borates. NBS J. Res., v. 68a (Physics and Chemistry), No. 5, September–October 1964, pp. 465–487.

[22] Chemical & Engineering News. Unsaturation Determined on Micro Scale. V. 42, No. 45, Nov. 9, 1964, p. 79.

[23] Chemical Week. Teamed To Tame Heat. V. 95, No. 16, Oct. 17, 1964, pp. 57–58, 60.

Direct information on known data about specific phases of boron chemistry and references to the original literature was contained in a published book titled "Boron, Metallo-Boron Compounds and Boranes."[25]

An investigation was conducted to determine the change in the mechanical properties of electron-beam-melted molybdenum by the addition of small quantities of boron and the optimum range of boron additions. The addition of small amounts of boron greatly improved the ductility of molybdenum ingots. The optimum amount of boron that produced grain refinement was 230 parts per million. Boron levels between 60 and 230 parts per million produced the greatest ductility in molybdenum sheets. Small amounts of boron increased the stress-rupture strength substantially above that of commercial unalloyed molybdenum and about twice that of high purity electron-beam-melted molybdenum. Embrittlement in the finished sheet was caused by boron in amounts greater than 230 parts per million.[26]

Heat-capacity investigations on potassium borohydride were conducted to obtain thermodynamic data on various boron compounds. Molal thermodynamic functions for potassium borohydride up to 700°K were presented.[27]

The chemical equilibrium among boron, nitrogen, and liquid iron in the range of steelmaking temperatures was investigated. Measurements were made of the solubility of nitrogen in liquid iron-boron alloys up to the solubility limit for the formation of boron nitride. Boron nitrogen interaction parameters were calculated from experimental data. A determination was made of the standard free energy of decomposition of boron nitride in liquid iron.[28]

An ionexchange resin was prepared that will sorb boron as boric acid. Columnar studies showed that the resin will remove boron from irrigation water and magnesium chloride brines. This boron-specific resin was efficiently regenerated.[29]

Several patents for the preparation of boron fuels were issued. One described an improved method for producing a liquid high-energy fuel by the reaction of ethylene and diborane in the gas phase. The reaction was carried out in the presence of a nonoxidizing diluent gas and a catalyst consisting of boron and aluminum halides.[30]

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[24] Chemical & Engineering News. Series To Review Organoboron Compounds. V. 42, No. 47, Nov. 23, 1964, p. 68.

[25] Chemical & Engineering News. New Books. V. 42, No. 48, Nov. 30, 1964, p. 76.

[26] Zumbrunnen, A. D., and J. M. Fritzpatrick. Grain Refinement and Improved Ductility in Molybdenum by Small Boron Additions. J. Less-Common Metals (The Netherlands), v. 7, No. 5, November 1964, pp. 356–367.

[27] Furukawa, George T., Martin L. Reilly, and Jeanette H. Piccirelli. Heat Capacity of Potassium Borohydride (KBH_4) From 15 to 375° K. Thermodynamic Properties From 0 to 700° K. NBS J. Res., v. 68a (Physics and Chemistry), No. 6, November–December 1964, pp. 651–659.

[28] Evans, Donald B., and Robert D. Pehlke. The Boron-Nitrogen Equilibrium in Liquid Iron. Trans. AIME, v. 230 (Met. Soc.), No. 7, December 1964, pp. 1657–1662.

[29] Kunin, Robert, and Albert F. Preuss. Characterization of a Boron-Specific Ion Exchange Resin. Ind. and Eng. Chem., Product Res. and Development, v. 3, No. 4, December 1964, pp. 304–306.

[30] Brault, Robert G., and George F Huff (assigned to Callery Chemical Co., Pittsburgh, Pa.). Preparation of High Energy Boron Containing Fuels. U.S. Pat. 3,124,617, Mar. 10, 1964.

British Patent 946,994 was granted for a method of reducing the iron content of sodium borate. The iron was precipitated with zinc carbonate.[31]

Two patents were granted for the preparation of diborane. One method comprised a reaction between a protolyzing acid and a metal borohydride.[32] The other process consisted of passing a stream of dry hydrogen gas through a reaction zone heated to 950° to 2,000° C containing a mixture of granular silica and boron material. The volatile boron hydrides formed were separated from the exit gases.[33]

A compact composed of abrasive crystalline material was patented. The tough, coherent, hard abrasive compact consisted of cubic boron nitride and diamonds bonded by boron carbide.[34]

A process was devised to manufacture boron carbide molding powers. The product of a reaction of boric acid with carbon which contained over 98 percent boron carbide a boron to carbide mole ratio from 3.65 to 4.05 was washed to remove impurities. The material was ground in a ball mill to produce a particle-size distribution of which 80 to 90 percent fell within a range from 5 to 50 microns with less than 12 percent under 5 microns and with no particle larger than 100 microns. Milled particles of 99 percent boron carbide and less than 0.1 percent iron was hotpressed into long-wearing molded products having little free carbon and few flaws.[35]

Iron, carbon, boron carbide, and iron carbide impurities were removed from finely divided particles of elemental boron by a patented method. Purified boron was separated from a vigorously agitated mixture of the boron particles, water, and oleic acid.[36]

A patented process for making cubic crystalline boron nitride subjected a mixture of an actinide or lanthanide metal, elemental boron or hexagonal boron, and nitrogen to elevated temperatures and pressures.[37]

A patent was issued for an improved process for making boron trichloride. Improvements were claimed by making adjustments in the initial mixture, adding a coke-forming binder to form agglomerates, charging the agglomerates into the top of a vertical reaction zone, and passing chlorine upwardly through the reaction zone.[38]

The synthesizing of boron carbide by the reaction of boron-oxide ore and coke in electric arc furnace was patented. The design and operation of the furnace resulted in the formation of a boron carbide ingot under each electrode.[39]

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[31] Chemical Trade Journal and Chemical Engineer (London). Boron Purification. V. 154, No. 4014, May 15, 1964, p. 712.

[32] Schultz, Robert D., and Carl L. Randolph, Jr. (assigned to Aerojet-General Corp., Azusa, Calif.). Method of Preparing Alkylated Boron Hydrides. U.S. Pat. 3,135,803, June 2, 1964.

[33] Kalb, George H. (assigned to E. I. du Pont de Nemours & Co., Inc., Wilmington, Del.). Process for Preparing Diborane. U.S. Pat. 3,148,029, Sept. 8, 1964.

[34] Bovenkerk, Harold P., Robert H. Wentorf, Jr., and Robert H. Savage (assigned to General Electric Co.). Compact of Abrasive Crystalline Material With Boron Carbide Bonding Medium. U.S. Pat. 3,136,615. June 9, 1964.

[35] Fetterley, Guy H. (assigned to Morton Co., Worcester, Mass.). Process for the Manufacture of Boron Carbide Molding Powers. U.S. Pat. 3,137,584, June 16, 1964.

[36] Schaefer, James C., and Ernest C. Schmidt (assigned to Walter M. Weil, Shaker Heights, Ohio). Purification of Boron. U.S. Pat. 3,137,647, June 16, 1964.

[37] Wentrof, Robert H. (assigned to General Electric Co.). Process for Making Cubic Crystal Boron Nitride. U.S. Pat. 3,150,929, Sept. 29, 1964.

[38] Bratt, Lars C., and Loren J. Hov (assigned to Stauffer Chemical Co.). Process for Making Boron Trichloride. U.S. Pat. 3,152,869, Oct. 13, 1964.

[39] Scott, John J. (assigned to Norton Co.). Arc Furnace Process for the Production of Boron Carbide. U.S. Pat. 3,161,471, Dec. 15, 1964.

Bromine

By William C. Miller[1]

❖

A CONTINUED growth in the outlets of bromine and bromine compounds as gasoline additives, fumigants, water sanitation chemicals, and flame retardants for plastics established a new production record for the United States. Exports of bromine, bromides, and bromates also reached a record high in 1964.

DOMESTIC PRODUCTION

Sales by primary producers of bromine and bromine compounds in 1964 increased 20 percent in quantity and 35 percent in value to reach a record level. The gain was attributed to increased sales of elemental bromine and of all bromine compounds except ammonium and ethyl bromides.

TABLE 1.—Sales of bromine and bromine compounds by primary producers in the United States

(Thousand pounds and thousand dollars)

Year	Quantity		Value
	Gross weight	Bromine content	
1955–59 (average)	222,703	189,007	$46,705
1960	206,948	175,010	44,637
1961	212,497	180,798	44,517
1962	223,972	190,747	46,617
1963	238,583	203,333	48,558
1964	286,813	241,302	65,316

Bromine was recovered from sea water bitterns by the FMC Corp. at Newark, Calif., and from sea water by the Ethyl-Dow Chemical Co. at Freeport, Tex. In Michigan, plants of The Dow Chemical Co. at Midland and Ludington, Great Lakes Chemical Corp. at Filer City, Michigan Chemical Corp. at St. Louis and Manistee, and the Morton Salt Co. at Manistee extracted bromine from natural well brines. Arkansas Chemical, Inc., and Michigan Chemical Corp. recovered bromine from oil well brines near El Dorado, Ark. Bromine was extracted from the brines of Searles Lake at Trona, Calif., by the American Potash & Chemical Corp.

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[1] Commodity specialist, Division of Minerals.

Great Lakes Chemical Corp., West Lafayette, Ind., announced the start of construction near El Dorado, Ark., of a bromine and bromine chemical plant with an estimated annual output of 10 to 15 million pounds. A long term agreement was concluded with DuPont of Canada, Ltd., to buy a substantial quantity of the plant's ethylene dibromide output.

Several new products were placed on the market during the year. Two liquid brominated organics, 9,10-dibromostearic acid and its methyl ester, soluble in a number of organic solvents, were used as flame retardants, fungicides, and chemical solvents. A brominated anhydride was marketed as a fire retardant in polyester resins. Granular sodium and potassium bromides that met National Formulary standards were produced for the manufacture of photographic and pharmaceutical chemicals.

TABLE 2.—Bromine and bromine compounds sold by primary producers in the United States

(Thousand pounds and thousand dollars)

Product	Quantity		Value
	Gross weight	Bromine content	
1963:			
Elemental bromine	26,248	26,248	$4,443
Methyl bromide	13,490	11,357	5,020
Other, including ethylene dibromide, sodium bromide, ammonium bromide, and potassium bromide	198,845	165,728	39,095
Total	238,583	203,333	48,558
1964:			
Elemental bromine	33,718	33,718	5,759
Ethyl bromide	955	823	383
Methyl bromide	14,381	12,553	6,524
Other, including ethylene dibromide, sodium bromide, ammonium bromide, and potassium bromide	237,759	194,208	52,650
Total	286,813	241,302	65,316

CONSUMPTION AND USES

Most bromine sold by primary producers in 1964 was consumed in the manufacture of ethylene dibromide. A resurgence in the demand for ethylene dibromide as a gasoline additive was one of the principal reasons for the increased consumption of bromine. The use of ethylene dibromide in grain and soil fumigates continued to grow during 1964.

Elemental bromine, the second largest sales item of the primary producers, showed the greater consumption growth rate, and increase of 28 percent over the 1963 consumption. Pharmaceutical and photographic uses and new applications for the high-purity bromine accounted for a considerable portion of the increased consumption of elemental bromine. The use of bromine for swimming-pool sanitizers continued to grow.

Methyl bromide ranked third in the sales of bromine. The major outlet was soil and grain fumigates. Another market for methyl bromide that showed a moderate growth was pesticides.

Consumption of potassium and sodium bromides showed increases, reversing the downward trend in 1963. They were used in medical and pharmaceutical preparations, photographic emulsions, and analytical reagents.

Brominated compounds, such as tris (2,3 di-bromopropyl) phosphate, tetrabromo phthalic anhydride, and tetrobromo bis-phenol-A, reportedly made a strong growth in the market for flame retardants for plastics. Hydrobromic acid used as an intermediate in other processes and 1,3 dibromo propane as a nematocide showed moderate growths.

PRICES

An increase of 1 cent per pound in the price of bromine in all categories was announced in December by The Dow Chemical Co. Spot purchases were effective immediately by the increase and contract purchases on January 1, 1965. The following prices were quoted by Oil, Paint and Drug Reporter:

	Cents per pound
Bromine, purified, cases, carlots, ton lots, delivered east of Rocky Mountains	32–33
Drums, carlots, ton lots, delivered east of Rocky Mountains	28–29
Tanks, carlots, same basis	21.5
Ammonium bromide, National Formulary (N.F.) granular, drums, carlots, ton lots, freight equalized	44
Bromochloromethane, drums, carlots, freight equalized	48
Tanks, same basis	47
Ethylene dibromide, drums, carlots, freight equalized	30.5
Tanks, freight equalized	28.5
Potassium bromate, 200-pound drums, carlots, freight allowed	49
Potassium bromide, U.S.P., granular, barrels, kegs	40
Sodium bromide, U.S.P., granular, barrels, drums, works	40

FOREIGN TRADE

Imports in 1964 of 200 pounds of bromine valued at $204 from Canada, 11 pounds of potassium bromide valued at $120 from West Germany, and 686 pounds of sodium bromide valued at $2,268 from West Germany and France cannot be compared with data for previous years. After adoption of the U.S. tariff schedules (TSUS), effective August 31, 1963, other classes became part of a blanket category and are no longer classified separately. Imports of bromine and bromine compounds in 1963 totaled 374,012 pounds valued at $167,615.

Bromine, bromides, and bromates exports increased for the second consecutive year to a record 17 million pounds valued at $3 million, compared with the revised figures for 1963 of 12.4 million pounds valued at $2.6 million. Exports to African, Asian, European, and Oceanian countries continued to increase while shipments to North and South American countries decreased. The increase of exports to Italy to 2.8 million tons in 1964 from 0.7 million tons in 1963 was outstanding.

TABLE 3.—U.S. exports of bromine, bromides, and bromates, by countries

Destination	1963		1964	
	Pounds	Value	Pounds	Value
North America:				
Canada	8,481,459	$1,465,195	7,893,703	$1,386,542
El Salvador	12,845	3,612	8,775	3,232
Guatemala	32,508	14,324	3,500	1,474
Mexico	399,169	196,529	799,657	206,159
Panama	1,800	849	27,504	7,046
Other	19,232	13,299	27,798	15,399
Total	8,947,013	1,693,808	8,760,937	1,619,852
South America:				
Argentina	19,937	10,448	20,317	11,745
Brazil	16,098	8,691	10,794	3,845
Colombia	8,770	6,251	2,770	1,309
Peru	248	720	2,448	1,628
Venezuela	36,594	18,267	31,260	15,910
Other	5,000	2,037	1,725	1,525
Total	86,647	46,414	69,314	35,962
Europe:				
Austria	6,704	3,774	-	-
Belgium-Luxembourg	33,189	11,856	8,115	6,492
Bulgaria	-	-	38,547	15,600
Denmark	2,388	1,251	6,216	4,605
France	97,661	60,019	71,031	36,232
Germany, West	43,030	46,580	42,955	26,922
Hungary	44,800	33,510	-	-
Italy	688,830	112,860	2,782,571	403,992
Netherlands	49,790	26,999	276,329	141,270
Spain	4,900	11,627	-	-
Sweden	1,904	772	20,621	6,741
Switzerland	90,851	32,392	87,851	70,586
United Kingdom	56,395	38,009	178,155	116,886
Other	13,600	5,740	66,79	3,166
Total	1,134,042	385,389	3,519,070	832,492
Asia:				
Burma	3,600	2,586	-	-
India	42,506	20,966	169,542	47,310
Indonesia	1,080	806	70,209	15,353
Iran	1,600	888	8,520	7,242
Japan	40,801	17,868	21,085	12,468
Pakistan	6,000	6,900	15,838	12,070
Philippines	12,738	8,385	194,780	57,744
Taiwan	-	-	31,374	11,269
Thailand	30,608	12,959	12,548	6,160
Viet-Nam	18,633	6,665	47,316	15,144
Other	12,396	6,924	10,740	7,255
Total	169,962	84,947	581,952	192,015
Africa:				
Malawi, Southern Rhodesia, and Zambia	r 1,675,740	r 275,996	2,238,300	426,322
Nigeria	49,880	13,986	-	-
South Africa, Republic of	229,358	44,287	1,379,661	234,886
Other	-	-	11,402	7,145
Total	r 1,954,978	r 334,269	3,629,363	668,353
Oceania:				
Australia	113,338	44,340	471,938	85,200
New Zealand	1,600	888	3,868	2,885
Total	114,938	45,228	475,806	88,085
Grand total	r 12,407,580	r 2,590,055	17,036,442	3,436,759

r Revised.

Source: Bureau of the Census.

WORLD REVIEW

Canada.—Construction of a tetraethyl lead antiknock compound plant in Maitland, Ontario, was announced by DuPont of Canada, Ltd. An agreement was reached for the importation of sodium and ethylene bromide from the United States. To achieve flexibility in the operation of the comparatively small plant, a conventional batch process was designed instead of a continuous process.

France.—Production of liquid bromine in 1963 increased to 2,098 short tons, compared with 1,786 tons in 1962.

Germany, West.—Production of elemental bromine and bromine compounds in 1963 was 2,358 short tons valued at $1.2 million.

Israel.—The Dead Sea Works, Ltd., devoted considerable effort to develop new products containing bromine, because difficulty was encountered from established competition in marketing ethylene dibromide. Two promising items were dibromotetrachloroethane, a weed-killing gas, and a chemical based on bromides, a disinfectant for citrus fruit trees.

The new Haifa plant of Israel Petrochemical Enterprises supplied the Sodom plant of the Dead Sea Works with the ethylene, which had previously been imported, for the production of ethylene dibromide.

Production of bromides in 1963 was 3,858 short tons. Exports of bromine compounds in 1963 totaled 3,242 tons valued at $989,000, compared with 2,419 tons valued at $957,000 in 1962.

Japan.—Elemental bromine production in 1963 totaled 3,596 short tons, compared with 2,920 tons (revised figure) in 1962. Potassium bromide output totaled 478 tons in 1963, compared with 418 tons in 1962.

TECHNOLOGY

N-bromo-compounds were found to be useful and selective oxidizing agents in a process for the synthesis of some rare sugars. Improved yield and high selectivity were obtained from the oxidation procedure.[2]

A study employing chronopotentiometry was made of the bromide-bromine couple at platinum and carbon paste electrodes.[3]

A new process for the recovery, purification, and concentration of metallic salts from solutions was reported. A bromide mixed with a common solvent was used in the process.[4]

Kinetic studies were made of the bromination of 8-quinolinol and 2-methyl-8-quinol. An instrumental technique capable of investigating the kinetics of fast reactions and a reaction scheme were developed. Determinations were made of the rates of mono- and dibromination of the compounds and of the specific rate constants for the various reaction steps.[5]

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[2] Kiss, J. Oxidations of Sugar Derivatives with Bromocarbamide. Chem. and Ind. (London), No. 2, Jan. 11, 1964, p. 73.

[3] Davis, D. G., and M. E. Everhart. Chronopotentiometry of the Bromide-bromine Couple at Platinum and Carbon Paste Electrodes. Anal. Chem., v. 36, No. 1, January 1964, pp. 38–40.

[4] Chemical Age (London). Separation of Non-ferrous Metals Using Bromides. V. 91, No. 2324, Jan. 25, 1964, p. 157.

[5] Kozak, Gary S., Quintus Fernando, and Henry Freiser. Kinetic Studies with Electrogenerated Halogens—Bromination of 8-Quinolinol and 2-Methyl-8-Quinolinol. Anal. Chem., v. 36, No. 2, February 1964, pp. 296–300.

A study of the bromination of chlorobenzene showed that the quantity of m-bromochloro-benzene produced was dependent upon the reaction time and catalyst used.[6]

Factors that influence the flame-retardant characteristics of brominated epoxy resins were investigated. A very important factor was the type of curing agent. An anhydride curing agent gave the best results. Epoxy resins based on tetrabromobisphenol A provided excellent flame-retardant characteristics.[7]

A continuous process for generating anhydrous hydrogen bromide was described. Dry gas hydrogen bromide was generated by the dehydration of aqueous hydrobromic acid.[8]

Various phases of the ethyl bromide radiation process used by a major bromine producer were described. The original laboratory work, laboratory prototype, reaction vessel, radiation intensity, and operating experiences were discussed.[9]

An investigation of the reactions of primary bromides and tosylates with alkoxides under preparative conditions was reported. Results indicated that the bromides underwent the elimination reaction while the tosylates gave good yields of substitution products. This difference can be significant in the development of synthetic procedures.[10]

The procedures used in a simplified method for the preparation of 2, 6-dibromo-4 nitrophenol were described. The use of bromine chloride in aqueous solution shortened the reaction time and eliminated the use of an acid solvent and liquid bromine.[11]

Data were obtained on energy and optimum power densities, cycling characteristics, and electrode polarization of a bromine-zinc secondary cell.[12]

A study was conducted to obtain absolute values for the isotopic abundance ratio and atomic weight of bromine. An absolute Br^{79}/Br^{81} ratio of 1.02784 ± 0.00190 and an atomic weight of 79.9363 ± 0.00092 were obtained.[13]

A process was patented for the recovery of bromine absorbed on an anion-exchange resin.[14]

A method of treating film materials with ammonium bromide was patented.[15]

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[6] Buck, K. R., N. M. Scollick, and D. Simpson. Bromination of Chlorobenzene. Chem. and Ind. (London), No. 12, Mar. 21, 1964, p. 494.

[7] Bremmer, Bart J. Heat Stability of Brominated Epoxy Resins. Product Research and Development, Ind. and Eng. Chem., v. 3, No. 1, March 1964, pp. 55–60.

[8] Sloan, A. D. B. Preparation of Anhydrous Hydrogen Bromide. Chem. and Ind. (London), No. 14, Apr. 4, 1964, p. 574.

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[12] Barnartt, Sidney, and David A. Forejt. Bromine-Zinc Secondary Cells. J. Electrochem. Soc., v. 111, No. 11, November 1964, pp. 1201–1204.

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Cadmium

By Harold J. Schroeder[1]

◆

THE DOMESTIC cadmium industry in 1964 experienced higher production, imports, and exports, but substantially lower calculated consumption. Disposal of 5 million pounds of cadmium from the Government stockpile was authorized, but sales amounted to only 23,400 pounds. Combined producer and distributor stocks of metal increased during the year from 1.4 to 2.2 million pounds. The quoted price of cadmium, in ton lots, was $3 per pound throughout the year.

TABLE 1.—Salient cadmium statistics

(Thousand pounds)

	1955-59 (average)	1960	1961	1962	1963	1964
United States:						
Production [1]	9,892	10,445	10,466	11,137	9,990	10,458
Shipments by producers [2]	10,244	11,982	10,222	12,057	10,124	9,689
Value thousands	$13,877	$14,721	$14,218	$18,481	$21,880	$27,412
Imports for consumption, metal	1,654	942	1,079	1,117	991	1,104
Exports	970	2,448	702	717	1,313	1,439
Consumption	9,563	[r] 10,126	[r] 10,184	[r] 12,146	[r] 11,482	9,365
Price: Average [3] per pound	$1.60	$1.52	$1.68	$1.72	$2.26	$3.00
World: Production	20,800	[r] 24,500	[r] 24,900	[r] 26,300	[r] 26,600	27,900

[r] Revised figure.

[1] Primary and secondary cadmium metal. Includes equivalent metal content of cadmium sponge used directly in production of compounds.

[2] Includes metal consumed at producer plants.

[3] Average quoted price for cadmium sticks and bars in lots of 1 to 5 tons.

LEGISLATION AND GOVERNMENT PROGRAMS

Public Law 88-319, signed by President Johnson on June 12, authorized General Services Administration (GSA) to dispose of 5 million pounds of cadmium from the Government stockpile. In accord with this authorization, GSA made available for sale 600,000 pounds of cadmium at market prices during the third quarter of 1964, with the sales for the first 2 months restricted to holders of defense rated orders. Sales in the restricted category amounted to 6,500 pounds and in the unrestricted category to 16,900 pounds. The lack of bids was attributed to some improvement in availability of cadmium through commercial channels and to the undesirability of shapes available for sale from the Government stockpile. No cadmium was made available for sale in the last quarter of 1964, but GSA announced that sales would resume in 1965.

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[1] Commodity specialist, Division of Minerals.

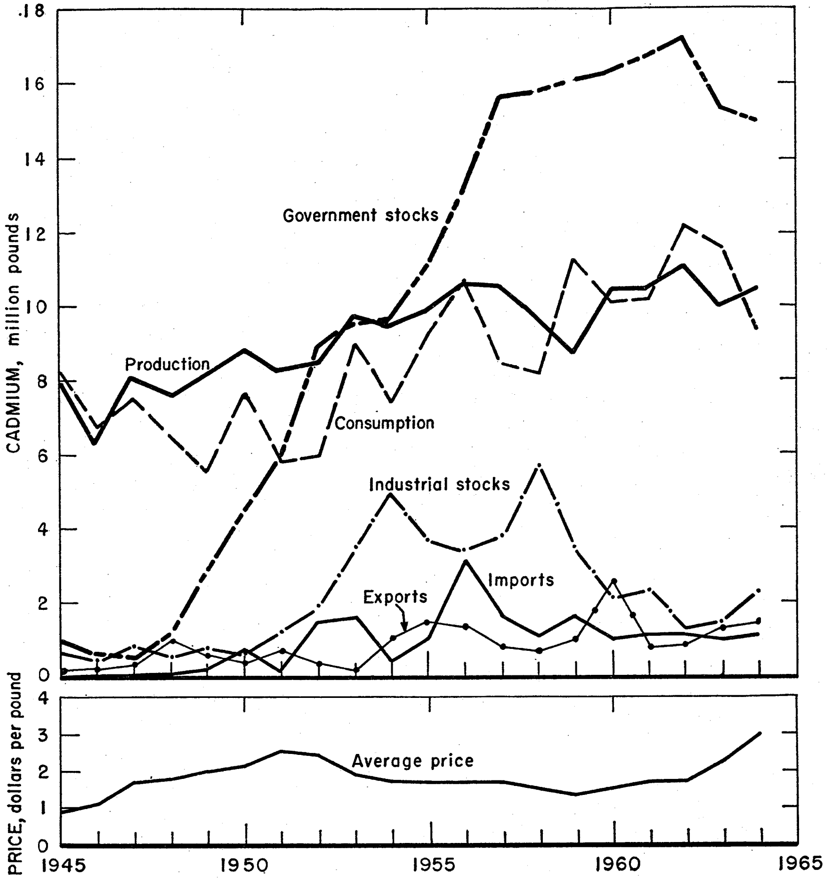

FIGURE 1.—Trends in production, consumption, yearend stocks, imports, exports, and average price of cadmium metal in the United States.

DOMESTIC PRODUCTION

About 11 percent of the 10.5 million pounds of cadmium production was derived from imported cadmium flue dust. Except for a relatively small quantity recovered from scrap, the balance was obtained from processing domestic and imported zinc and other base metal concentrates with the foreign source estimated to be the largest item. The main sources of imported zinc concentrates were Mexico, Canada, and Peru. Secondary cadmium was recovered mainly from scrap alloys.

The following plants produced cadmium metal in the United States in 1964:

American Smelting and Refining Company, Denver, Colo., and Corpus Christi, Tex.
American Zinc Co. of East St. Louis, Ill.
The Anaconda Company, Great Falls, Mont.

Blackwell Zinc Co., Blackwell, Okla.
The Bunker Hill Co., Kellogg, Idaho.
The Eagle-Picher Co., Galena, Kans.
National Zinc Co., Inc., Bartlesville, Okla.
The New Jersey Zinc Co., Palmerton, Pa.
St. Joseph Lead Co., Josephtown, Pa.
Sherwin-Williams Co., Coffeyville, Kans.
United Refining & Smelting Co., Chicago, Ill.

TABLE 2.—Cadmium oxide and cadmium sulfide produced in the United States

(Thousand pounds)

Year	Oxide		Sulfide [1]	
	Gross weight	Cadmium content	Gross weight	Cadmium content
1955–59 (average)	W	W	3, 582	1, 175
1960	1, 275	1, 124	3, 484	1, 084
1961	1, 229	1, 075	3, 355	1, 115
1962	1, 694	1, 481	4, 250	1, 329
1963	W	W	4, 560	1, 542
1964	W	W	4, 514	1, 531

W Withheld to avoid disclosing individual company confidential data.
[1] Includes cadmium lithopone and cadmium sulfoselenide.

CONSUMPTION AND USES

Consumption of cadmium metal—calculated as production and plus or minus net foreign trade and net changes of known industrial and Government stocks—was 9.4 million pounds. This quantity was an 18-percent decrease from 1963 and the smallest since 1958.

Plating continued to be the largest use for cadmium, and was estimated to have consumed 55 to 60 percent of the total. Applications for cadmium plating include parts for automobiles, household appliances, aircraft, industrial machines, radio and television sets, electrical and electronic equipment, and hardware fittings, instruments, and numerous fastening items such as nuts, bolts, and screws.

Pigments, the second largest use, accounted for an estimated 15 to 20 percent of consumption. The cadmium compounds employed for high-quality industrial yellow and red colors are the sulfide, sulfoselenide, and lithopones. Cadmium compounds used for other than colors represent about 15 to 20 percent of consumption. Large and growing applications in this classification are the stearate for vinyl plastics, the nitrate for nickel-cadmium batteries, and phosphors for television tubes.

Cadmium is used as a component of solders, low-melting point fusible alloys, and for other alloys amounting in the aggregate to an estimated 8 to 11 percent of total use.

STOCKS

Government stockpiles were reduced by 23,400 pounds during 1964 to 15.1 million pounds, of which 7.7 million was in the strategic stockpile and 7.4 million in the supplemental stockpile The stockpile objective was 5.1 million pounds.

TABLE 3.—Industry stocks, December 31

(Thousand pounds)

	1963		1964	
	Cadmium metal	Cadmium in compounds	Cadmium metal	Cadmium in compounds
Metal producers	755	(1)	1,523	(1)
Compound manufacturers	488	r 777	311	756
Distributors	r 136	55	326	81
Total	r 1,379	r 832	2,160	837

r Revised.

[1] Included with stocks of cadmium contained in compounds at compound manufacturers in order to avoid disclosing individual company confidential data.

PRICES

Quoted prices for cadmium metal for producer to consumer remained unchanged during the year at $3 per pound for lots of 1 ton and $3.05 for lots of less than 1 ton. The quoted distributor to consumer price was $3.50 per pound until May 15, and thereafter, $3.25 to $3.45 per pound.

Cadmium on the London market was quoted at the beginning of the year at 24s. per pound ($3.35). Price quotations changed on March 20 to 25s. ($3.49), and on September 8 to 22s. ($3.07).

In Italy the quoted price was 6,000 lire per kilogram at the beginning of the year, or $4.36 per pound. After advancing to 6,100 lire ($4.43) on January 9, prices declined during the remainder of the year and were 3,800 lire ($2.76) at yearend.

The French quotation for metal began the year at 39 francs or $3.61 per pound. After advancing to 45 francs ($4.16) on January 20, prices declined during the remainder of the year and were 28 francs ($2.59) at yearend.

FOREIGN TRADE

Imports.—General imports of cadmium metal were 1.1 million pounds, 12 percent above 1963; Canada, Congo (Léopoldville), and Peru supplied 71 percent of the total. Imports of cadmium in flue dust, all from Mexico, increased 7 percent to 1.3 million pounds.

TABLE 4.—U.S. imports of cadmium metal and cadmium in flue dust, by countries

(Thousand pounds and thousand dollars)

Country	General imports[1]				Imports for consumption[2]			
	1963		1964		1963		1964	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
CADMIUM METAL								
North America:								
Canada	623	$1,370	428	$1,084	623	$1,370	428	$1,084
Mexico	17	39	96	293	17	39	94	286
Total	640	1,409	524	1,377	640	1,409	522	1,370
South America:								
Argentina	41	98	2	6	22	56	3	8
Chile	11	16	-----	-----	11	16	-----	-----
Peru	119	168	152	342	119	168	152	342
Total	171	282	154	348	152	240	155	350
Europe:								
Belgium-Luxembourg	35	77	78	204	31	66	78	204
Germany, West	10	18	-----	-----	10	18	-----	-----
Italy	-----	-----	-----	-----	1	2	-----	-----
Netherlands	40	82	4	11	40	82	4	11
Poland-Danzig	1	4	-----	-----	1	4	-----	-----
Total	86	181	82	215	83	172	82	215
Asia: Japan	51	90	102	288	53	94	86	247
Africa:								
Congo (Léopoldville)	2	4	223	591	2	4	218	575
Burundi and Rwanda			-----	-----			-----	-----
Total	2	4	223	591	2	4	218	575
Oceania: Australia	61	145	44	122	61	145	41	113
Total cadmium metal	1,011	2,111	1,129	2,941	991	2,064	1,104	2,870
FLUE DUST (CADMIUM CONTENT)								
North America: Mexico	r 1,189	r $913	1,272	$1,543	r 1,104	r $863	1,272	$1,543
Europe: Belgium-Luxembourg	-----	-----	(3)	2	-----	-----	(3)	2
Total flue dust	r 1,189	r 913	1,272	1,545	r 1,104	r 863	1,272	1,545
Grand total	r 2,200	r 3,024	2,401	4,486	r 2,095	r 2,927	2,376	4,415

r Revised.

[1] Comprises cadmium imported for immediate consumption plus material entering bonded warehouses.

[2] Comprises cadmium imported for immediate consumption plus material withdrawn from bonded warehouses.

[3] Less than ½ unit.

Source: Bureau of the Census.

Exports.—Exports of cadmium as metal and alloys, dross, flue dust, residues and scrap increased 10 percent to 1.4 million pounds, the largest quantity since 1960. The United Kingdom and the Netherlands received 83 percent of total exports.

TABLE 5.—U.S. exports of cadmium metal and cadmium in alloys, dross, flue dust, residues, and scrap

(Thousand pounds and thousand dollars)

Year	Quantity	Value	Year	Quantity	Value
1955–59 (average)	970	$1,345	1962	717	$1,139
1960	2,448	3,014	1963	1,313	3,070
1961	702	983	1964	1,439	4,033

Source: Bureau of the Census.

Tariff.—The import duty on cadmium metal remained at 3.75 cents per pound in 1964—the rate effective January 1, 1948, as established at the Geneva Trade Conference in 1947. Cadmium contained in flue dust remained duty free.

WORLD REVIEW

World production of cadmium metal increased 5 percent to 27.9 million pounds. Five countries—United States, U.S.S.R., Canada, Japan, and Belgium—accounted for about 76 percent of the total. Countries with the largest increases were Canada, France, and the United States.

TABLE 6.—World production of cadmium metal by countries [1] [2]

(Thousand pounds)

Country	1955–59 (average)	1960	1961	1962	1963	1964
North America:						
Canada	2,109	2,357	1,358	2,605	2,475	[e] 2,801
Honduras	----------	10	10	34	73	[e] 75
Mexico [3]	73	179	104	63	326	[e] 65
United States	9,892	10,445	10,466	11,137	9,990	10,458
South America: Peru	79	185	232	235	382	[e] 450
Europe:						
Austria	[4] 25	32	42	49	41	[e] 45
Belgium	1,449	[3] 1,583	[3] 1,988	[3] 1,854	[3] 1,943	[e] [3] 1,850
France	390	560	560	567	578	881
Germany, West	719	902	952	560	492	705
Italy	501	648	765	546	616	510
Netherlands [e]	64	88	88	88	88	88
Norway	260	243	231	254	243	249
Poland [e]	620	860	880	880	930	930
Spain	19	26	76	133	119	[e] 120
U.S.S.R.	1,700	3,000	3,300	3,500	3,700	3,900
United Kingdom [5]	281	236	217	237	246	420
Yugoslavia	40	84	[e] 88	[e] 88	[e] 88	[e] 88
Asia: Japan	912	1,252	1,596	1,948	2,231	[e] 2,231
Africa:						
Congo (Léopoldville) Republic of the	803	1,113	1,173	677	871	[e] 900
Zambia	[4] 70	58	42	37	33	[e] 35
Oceania: Australia	745	672	697	791	1,089	[e] 1,045
World total (estimate)	20,800	24,500	24,900	26,300	26,600	27,900

[e] Estimate.

[1] Data derived in part from bulletins of the World Non-Ferrous Metal Statistics (London) and annual issues of Metal Statistics (Metallgesellschaft).

[2] This table incorporates some revisions. Data do not add exactly to totals shown because of rounding where estimated figures are included in the detail. No estimate included for Bulgaria, but it is reported to be producing cadmium.

[3] Exports.

[4] Average for 1956–59.

[5] Including secondary.

Japan.—Six of the leading Japanese cadmium producers entered into an agreement with Mining and Chemical Products, Ltd., of London, to be the producers' exclusive agent for export sales.

Mexico.—A zinc reduction plant including facilities for 240 tons annual output of cadmium was nearing completion at yearend. The facilities are being constructed at Saltillo, Coahuila, by Zincamex, S.A., a company formed by the Mexican Government. Exports of cadmium contained in concentrates and flue dust was reported to be 2.1 million pounds in 1963 and estimated to be 1.2 million pounds in 1964.

South-West Africa.—The Tsumeb Corp., Ltd., completed a 400,000-pound-per-year cadmium plant in conjunction with recently constructed lead and copper smelting facilities. The plant was not operated in 1964, due in part to the need to recirculate the lead baghouse dust until the cadmium content is increased sufficiently to warrant extraction. Exports of cadmium contained in concentrates was reported to be 1.1 and 0.7 million pounds in 1963 and 1964, respectively.

United Kingdom.—"The World Non-Ferrous Metal Statistics" published by the British Bureau of Non-Ferrous Metal Statistics reports production of 420,000 pounds and imports of 3,524,000 pounds of cadmium for the United Kingdom during 1964. Cadmium consumption was 3.0 million pounds and was used for the following purposes (in thousand pounds): Plating anodes, 877; plating salts, 186; cadmium-copper alloys, 104; other alloys, 68; alkaline batteries, 224; dry batteries, 12; solder, 235; colors, 1,222; and miscellaneous, 87.

TECHNOLOGY

The Bolivian National Department of Geology made a study of the distribution of cadmium in zinc ores in Bolivia. Ore in the Berenguela district is said to contain from 3 to 15 percent cadmium.[2] A geological investigation in the United States provided data on the distribution of cadmium in certain formations of the Great Plains Region.[3]

An article presented results of a survey of production practices of cadmium producers in the Western Hemisphere.[4] Another article described studies of fractional distillation of cadmium using a radioactive tracer technique.[5]

The Federal Bureau of Mines reported research on a method of cadmium extraction [6] and determined certain properties of cadmium sulfide.[7]

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[2] World Mining. V. 17, No. 6, June 1964, p. 52.

[3] Tourtelot, Harry A., Claude Huffman, and Lewis F. Ruder. Cadmium in Samples of the Pierre Shale and Some Equivalent Stratigraphic Units, Great Plains Region. U.S. Geol. Survey Prof. Paper 475 D, 1964, pp. D73–D78.

[4] Lund, R. E., and R. E. Sheppard. Cadmium Purification Practice in Zinc Smelting. J. Metals, v. 16, No. 9, September 1964, pp. 724–730.

[5] Akerman, Dr. Karol, Marek Brafman, Dr. Henryk Fik, Maciej Nowak, and Klemens Kruszewski. A Study by Means of Radioactive Tracers of a Fractional Distillation Process for Refining Cadmium. J. Inst. Metals (London), v. 93, pt. 4, December 1964, pp. 106–108.

[6] Lansche, Arnold M., and D. H. Chambers. Cadmium Refining by Amalgam Electrolysis. BuMines Rept. of Inv. 6352, 1964, 17 pp.

[7] Adami, L. H., and E. G. King. Heats and Free Energies of Formation of Sulfides of Manganese, Iron, Zinc, and Cadmium. BuMines Rept. of Inv. 6495, 1964, 10 pp.

Several articles described investigations on hydrogen embrittlement of high-strength steels plated with cadmium.[8]

A study was made of the annealing spectra of a number of silver-cadmium alloys over the temperature range of 25–600° C.[9] Research indicated that the apparent discrepancy between measured and X-ray densities of cadmium-magnesium solid solutions was due to microporosity in the specimens instead of vacant lattice sites as previously suggested.[10] A patent was granted for a cadmium brazing alloy (containing approximately 4.0–5.8 percent silver, 0.005–0.5 percent copper, and 0.10–0.45 percent zinc) with a melting point of about 675° F and a shear strength of 15,000–18,500 psi.[11]

A method of obtaining high purity cadmium sulfide by partial sublimation in a gas flow was described.[12] Patents were granted on producing and use of cadmium-acetate catalysts.[13]

Research found that the rate of oxygen recombination in sealed nickel-cadmium cells was proportional to the amount of metallic cadmium on the negative electrode, a variable that is a function of the state-of-charge on the electrode.[14]

In electronic applications of cadmium compounds, research was conducted on the effect of temperature treatment of photoconductors,[15] properties of cadmium halophosphate phosphors,[16] and a method of vacuum deposition of cadmium sulfide to form transducers which generate predominantly transverse waves.[17] Patents were granted for methods of producing and processing zinc-cadmium sulfide phosphors, and a controlled vaporization-deposition technique for manufacture of a cadmium-sulfide transistor.[18]

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[8] Beck, W. Effect of Cathodic Charging and Cadmium Plating on the Fatigue Behavior of High-Strength Steels. Electrochem. Tech., v. 2, No. 3–4, March–April 1964, pp. 74–78.

Dougherty, E. E. Methods for Minimizing Hydrogen Embrittlement in Electroplated High Strength Alloy Steels. Plating, v. 51, No. 5, May 1964, pp. 415–422.

[9] Kamel, R., and E. A. Attia. Annealing Spectrum of Cold-Worked Silver-Cadmium Alloys. J. Inst. of Metals (London), v. 92, pt. 9, May 1964, pp. 270–274.

[10] Ridley, N. Densities of Cadmium-Rich Cadmium-Magnesium Solid Solutions. J. Inst. Metals (London), v. 93, pt. 2, October 1964, pp. 46–47.

[11] Cape, Arthur T. (assigned to Coast Metals, Inc., Little Ferry, N.J.). Brazing Alloy, U.S. Pat. 3,124,453, Mar. 10, 1964.

[12] Vecht, A., B. W. Ely, and A. Apling. Purification of CdS by Partial Sublimation in a Gas Flow. J. Electrochem. Soc., v. 111, No. 6, June 1964, pp. 666–668.

[13] Hubner, Gerhard (assigned to Wacker-Chemie G.m.b.H., Munich, Germany). Process for Manufacturing Zinc and Cadmium Acetate-Activated Carbon Catalysts, U.S. Pat. 3,150,106, Sept. 22, 1964.

Congiundi, Nicholas R., and Lloyd T. Jenkins (assigned to Monsanto Co.). Preparation of Polyester Amides with Cadmium Acetate Catalyst, U.S. Pat. 3,153,012, Oct. 13, 1964.

[14] Turner, Dennis R. The Effect of State-of-Charge of the Cadmium Electrode on Oxygen Recombination in Sealed Nickel-Cadmium Cells. Electrochem. Technol., v. 2, No. 11–12, November–December 1964, pp. 313–319.

[15] Weiss, Ronald D. Permanent and Quasi-Permanent Photoconductivity Changes in Cadmium Sulfide-Cadmium Selenide Type Photoconductors. Electrochem. Technol., v. 2, No. 11–12, November–December 1964, pp. 347–351.

[16] Ropp, R. C. Cadmium Halophosphate Phosphors. J. Electrochem. Soc., v. 111, No. 9, September 1964, pp. 1091–1093.

[17] Electronic News. V. 9, No. 462, Nov. 23, 1964, p. 42.

[18] Lehmann, Willi (assigned to Westinghouse Electric Corp., East Pittsburgh, Pa.). Method of Preparing Cubic Zinc-Cadmium Sulfide Electroluminescent Phosphor, U.S. Pat. 3,140,999, July 14, 1964.

Lehmann, Willi (assigned to Westinghouse Electric Corp., East Pittsburgh, Pa.). Method for Processing Zinc-Cadmium Sulfide Electroluminescent Phosphor, U.S. Pat. 3,133,027, May 12, 1964.

Ravich, Leonard E. (assigned to Hupp Corp., Cleveland, Ohio). Introduction of Disturbance Points in a Cadmium Sulfide Transistor, U.S. Pat. 3,162,556, Dec. 22, 1964.

Calcium and Calcium Compounds

By E. C. Peterson[1]

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THE Government-owned magnesium and calcium redistillation facility at Canaan, Conn., was sold to Nelco Metals, Inc., a division of Chas. Pfizer & Co., Inc. The company, sole domestic producer of calcium, announced that an intensive research program has been launched to develop new industrial applications for both magnesium and calcium metal.

Domestic production and consumption of calcium chloride continued to increase in 1964, principally because of greater demand for ice control purposes.

DOMESTIC PRODUCTION

In 1964, production of calcium was about the same as in the previous year, according to Nelco Metals, Inc. Calcium continued to be produced by the thermal reduction of quicklime (calcium oxide) at elevated temperatures in vacuum retorts at the company's Canaan, Conn., plant. Two steps of distillation followed the reduction process to increase the purity of the calcium.

Special low-cost calcium-silicon alloys were manufactured by Vanadium Corp. of America, New York, N.Y.

Shipments of natural and synthetic solid calcium chloride (73 to 75 percent $CaCl_2$) and flake calcium chloride (77 to 80 percent $CaCl_2$) were 680,000 short tons in 1963, valued at $21 million ($30.88 per ton) f.o.b. plant. Brine shipments (40 percent $CaCl_2$) weighed 235,000 tons, valued at $2.3 million ($11.06 per ton) f.o.b. plant. Production of natural and synthetic solid and flake calcium chloride was 679,000 tons in 1963; production of calcium chloride brine was 235,000 tons, excluding all brine that went into the production of solid and flake calcium chloride.[2]

The reported domestic production of all forms of natural calcium chloride and calcium-magnesium chloride, reduced to a 75-percent-chloride and 25-percent-water basis, averaged 457,374 short tons per year during the period 1960–64. Value averaged $8.89 million ($19.43 per ton) for the same 5-year period. Production reached an alltime high in 1964. Tonnage increased 15 percent, and value increased 11 percent over 1963.

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[1] Commodity specialist, Division of Minerals.

[2] U.S. Department of Commerce, Bureau of the Census, Industry Division. Inorganic Chemicals and Gases, 1963. Current Ind. Rept. Ser. M28A(63)-13, Nov. 25, 1964, p. 11.

Eight plants produced natural calcium chloride (and calcium-magnesium chloride) from natural brines in 1964: Two in California, five in Michigan, and one in West Virginia. Michigan was the leading State with 95 percent of the reported production; California produced 4 percent, and West Virginia produced 1 percent. The two producers in California recovered calcium chloride from the brine of Bristol Lake. In Michigan and West Virginia, calcium chloride was recovered from well brines. Domestic production on a calcium chloride content basis was 72 percent flake, 28 percent brine, and less than 1 percent solid. Synthetic calcium chloride was manufactured by Allied Chemical Corp., Solvay Process Division, and by Pittsburgh Plate Glass Co., Chemical Division.

Optical grade calcite was mined by U.S. Calcite Co. near Convert Lake, Calif. A reported 3.5 pounds of the material was produced valued at $2,058.

Calspar Mining Co. is reportedly excavating what appears to be the largest single calcite crystal deposit in the world at Penasco, N. Mex. The fragments of clear calcite have an estimated total weight of nearly 30 tons.

Michigan Chemical Corp. was constructing a new plant at St. Louis, Mich., to produce 94 to 97 percent granular calcium chloride. The $2 million project will have an initial capacity of 40,000 tons of $CaCl_2$ a year and is expected to be in operation by the spring of 1965.

CONSUMPTION AND USES

Calcium metal continues to be used principally as a reducing agent in the metallurgy and production of a wide range of metals and alloys.

Low-cost alloys of calcium-silicon or calcium-manganese-silicon were used as reducing and deoxidizing agents in the production of many metals and alloys. Calcium's affinity for oxygen, nitrogen, sulfur, and halides made it ideal for the reduction of impurities from metals. These calcium alloys are made by reducing a charge of lime and silica in electric furnaces.

Based on more than a decade of satisfactory experience, the State of Tennessee's road engineers have developed confidence in calcium chloride treatment of dense-graded aggregate. The engineers have found that the chemical maintains uniform, optimum moisture content, which prevents aggregate segregation and materially aids compaction to high density requirements. Calcium chloride treated bases are also quickly compacted during initial rolling even in the hottest weather.

An 18-mile section of Interstate Highway 40 west of Nashville under construction spotlights Tennessee's practice of making flexible pavement bases with a combination of treated materials. For this section of highway, the design included 8 inches of dense-graded aggregate base, calcium chloride treated, extending out-to-out of shoulders, and under the paved width 7 inches of crushed stone bit.[3]

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[3] Road and Streets. Combined Base for a Large Interstate Project. V. 107, No. 5, May 1964, pp. 40–42, 44–45.

Continued increased demand of solid calcium chloride for ice control was evident in 1964. Pennsylvania reportedly raised its requirements of calcium chloride from 40,000 tons in 1963 to 57,000 tons in 1964. Virginia also raised its requirements during this period from 25,000 to 35,000 tons; Ohio asked for 17,000 tons, 12,000 tons more than in 1963. End uses of solid calcium chloride were as follows: Ice control, 30 percent; dust control, 25 percent; concrete treatment, 13 percent; industrial uses, 10 percent; brine refrigeration, 5 percent; and miscellaneous, 17 percent.[4]

Use of calcium chloride as an accelerating admixture in cold weather concreting kept pace with increased construction activity. Among the many favorable reports indicating that this use would continue to grow was a study of the effects of calcium chloride on the durability of concrete. Its authors concluded that the use of 2 percent calcium chloride as an additive gives concrete accelerated early strength gain "* * * without materially adversely affecting later strengths and without reducing the durability of the concrete involved."[5]

PRICES AND SPECIFICATIONS

The New York price of calcium, 97 to 98 percent pure, cast in slabs and small pieces, in ton lots, was quoted at $2.05 a pound in 1964.[6] This price has not changed, at least as far back as the beginning of 1952. Smaller quantities were quoted at the following prices per pound throughout the year: 100 pounds to 1 ton—$1.25, and small lots, 99.9 percent pure—$2.60.[7]

Chas. Pfizer & Co., Inc., New York, N.Y., offered two grades of calcium produced by its subsidiary, Nelco Metals, Inc., Canaan, Conn. Commercial-grade calcium, in percent, was calcium, over 99; magnesium, 0.50; aluminum, 0.30; nitrogen, 0.08; iron, 0.008; and manganese, 0.01. Redistilled-grade calcium expressed in percent, was calcium, over 99; magnesium, 0.50; nitrogen, less than 0.02; aluminum, less than 0.0010; iron, less than 0.0010; manganese, less than 0.0020; cobalt, less than 0.0002; lithium, less than 0.0001; beryllium less than 0.0001; chromium, less than 0.0002; and boron, less than 0.0001. Commercial-grade calcium was supplied as full crowns, broken crowns (5 inches and less), 6-mesh nodules, turnings, ingots, and waffles. Redistilled-grade calcium was supplied as broken crowns (8 inches and less), 6-mesh nodules, and one-eighth-inch nodules.

Most calcium chloride prices did not change in 1964. Powdered calcium chloride, 77 percent minimum $CaCl_2$ (paper bags, carlots, at works, freight equalized), was $40 per ton. Solid calcium chloride, 73 to 75 percent $CaCl_2$ (carlots, freight equalized), was $32.50 per ton. Calcium chloride liquor or brine, about 40 percent $CaCl_2$, a supersaturated solution shipped in heated tank cars (tank cars, freight equalized), was $14 per ton. Concentrated flake or pellet chloride,

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[4] Oil, Paint, and Drug Reporter. Calcium Chloride Supplies Improve, But Makers See Tight Winter Ahead. V. 186, No. 4, July 27, 1964. p. 31.

[5] Whitehurst, E. A., and A. B. Moore. The Effect of Calcium Chloride as an Accelerating Admixture Upon the Durability of Concrete. Tennessee Highway Research Program, Reprint No. 15, March 1964, 13 pp.

[6] E. & M.J. Metal and Mineral Markets. V. 35, Nos. 1–52, Jan. 6–Dec. 28, 1964.

[7] American Metal Market. V. 71, Nos. 1–252, Jan. 2–Dec. 31, 1964.

94 to 97 percent $CaCl_2$ (paper bags, carlots, at works, freight equalized), was $41.70 per ton from January 1 until March 1, when it was raised to $43 per ton. The price remained constant for the remainder of 1964. Regular flake calcium chloride, 77 to 80 percent $CaCl_2$ (paper bags, carlots, at works, freight equalized), was $34 per ton until March 1, when it was raised to $35 per ton.[8]

FOREIGN TRADE

Canada was the only source of imported calcium. Calcium chloride was imported from Belgium-Luxembourg, 68 percent; Canada, 15 percent; United Kingdom, 12 percent; and West Germany, 5 percent.

Calcium and calcium-silicon were not exported. Approximately 92 percent of the calcium chloride exported went to Canada and Mexico; Canada received over four-fifths of the total. The remaining 8 percent was distributed among 46 other countries. These other market areas in decreasing order of size, were South America, Asia, Europe, Africa, Central America, West Indies, and Oceania.

TABLE 1. U.S. imports for consumption of calcium, calcium-silicon, and calcium chloride and exports of calcium chloride

Year	Imports						Exports	
	Calcium		Calcium-silicon		Calcium chloride		Calcium chloride	
	Pounds	Value	Pounds	Value	Short tons	Value	Short tons	Value
1955–59 (average)	151,102	$183,168	486,428	$76,987	1,736	$61,410	35,758	$1,198,879
1960	12,618	15,276	352,765	50,899	1,570	61,938	26,792	1,067,909
1961	17,266	22,892	558,009	82,561	3,022	102,680	22,047	1,090,583
1962	43,962	51,669	1,370,048	200,163	1,896	59,753	43,830	1,686,819
1963	26,343	31,648	(1)	(1)	2,234	r 67,225	36,984	1,527,243
1964	42,439	42,238	(1)	(1)	2,718	91,933	39,893	1,513,479

r Revised.

[1] No longer separately classified, effective Sept. 1, 1963; Jan. 1–Aug. 1, 1963—119,308 pounds, value $159,575

Source: Bureau of the Census.

WORLD REVIEW

Canada.—Calcium production in 1964 was estimated at 158,875 pounds valued at Can$174,762 compared with 98,673 pounds valued at Can$117,247 in 1963, and 123,511 pounds valued at Can$124,412 in 1962.[9]

Calcium shipments totaled 92,100 pounds valued at Can$109,069 in 1963, compared with 104,850 pounds valued at Can$102,438 in 1962. Dominion Magnesium Ltd., with a plant at Haley, Ontario, was the only calcium metal producer. Calcium was produced by the thermal reduction of quicklime (calcium oxide) with powdered aluminum in vacuum retorts. The four grades of calcium metal available from Haley ranged in purity from the commercial grade (98 to 99 percent calcium) to the chemical standard grade (99.9 percent calcium). Maximum impurities in the commercial grade are 0.5 to 1.5 percent magnesium, 1.0 percent nitrogen, and 0.35 percent aluminum. Impurities become progressively less in other grades and are present only in trace amounts in the chemical standard grade which is available only in the form of granules (4 to 80 mesh). Commercial grade is available as crystalline lumps, granules, extruded rods and bars, billets, and 5-pound ingots. The Canadian prices quoted by Dominion Magnesium, Ltd., throughout 1963 ranged from Can-$0.80 a pound for commercial grade to Can$3.50 a pound for chemical standard grade, f.o.b. Haley. Calcium was exported to the following countries: United States, 28 percent; West Germany, 21 percent; India, 18 percent; Belguim-Luxembourg, 14 percent; Great Britain, 10 percent; and Italy, 9 percent. The U.S. tariff on imported Canadian calcium was 15 percent ad valorem. The Canadian most-favored-nation tariff on calcium metal, pure, in lumps, ingot, and powder was 15 percent ad valorem, and on calcium-metal alloys, or metal in rods, sheets, or semiprocessed form was 20 percent ad valorem.[10]

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[8] Oil, Paint, and Drug Reporter. V. 184, Nos. 1–26; v. 185, Nos. 1–26; Jan. 6–Dec. 28, 1964.

[9] Canada Department of Mines and Technical Survey, Mineral Resources Division (Ottawa, Canada). The Canadian Mineral Industry in 1964 (Preliminary). Miner. Inf. Bull. MR 79, February 1965, pp. 2–3.

EUROPE

Belgium.—Société Anonyme d'Applications de Chimie Industrielle (Sadaci) and Société Belge d'Electrochimie, Belgium's leading calcium carbide producers were merged. Since the plants of the two companies are on adjacent sites, it is expected that production costs will be lowered.[11]

Rumania.—Calcium chloride of comparatively high purity, mainly for export trade to Communist bloc countries, was produced at the Borzesti and Tirnaveni chemical combines. At the Borzesti plant calcium chloride is produced by the reaction between hydrochloric acid and calcium carbonate, and at Tirnaveni, the chloride is produced by the action of chlorine on hydrated lime. With both processes a solution containing 42 percent of calcium chloride is obtained. Part of this is marketed as such and part is further concentrated.[12]

Spain.—Construction of a calcium chloride plant and a polyvinyl chloride producing plant near Sogamoso was proposed by the Oficina de Planeación de Boyacá. Cost would be approximately 16.7 million pesos and 47.3 million pesos respectively.[13]

United Kingdom.—The 86,000-ton-per-year calcium chloride plant at the Winnington Works of the Imperial Chemical Industries, Ltd. (ICI) Mond Division was placed on stream during 1964.

Calcium chloride is made by concentrating the clear brine liquor from the distallation plant and removing the impurities. The liquor is put through a double effect evaporator system, and the concentrated solution then passes through two filter stages and is washed to remove salt.[14]

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[10] Jackson, W. H. Calcium 1963. Canada Dept. Mines and Tech. Surveys, Miner. Res. Div. (Ottawa, Canada) May 1964, 4 pp.

[11] Oil. Paint, and Drug Reporter. Calcium Carbide Merger. V. 185, No. 14, Apr. 6, 1964, p. 7.

[12] Chemical Trade Journal and Chemical Engineer (London). Rumanian Synthetic Calcium Chloride. V. 154, No. 4020, June 26, 1964, p. 929.

[13] Chemical Trade Journal and Chemical Engineer (London). V. 155, No. 4026, Aug. 7, 1964, p. 180.

TECHNOLOGY

Use of pulverized calcium carbonate to control pH in the range of 5 to 6 during commercial bleaching was announced by a Canadian paper company. By maintaining pH near neutral during the bleaching period, it is possible to use very high bleaching temperatures, resulting in maximum brightness and color stability without deterioration of pulp strength. A saving in chemical costs of approximately 50 cents per ton of pulp is realized by eliminating the caustic soda neutralization step formally necessary after acid bleaching.[15]

Single crystals of calcium orthovanadate $Ca_3(VO_4)_2$ up to 10 centimeters long and 1.25 centimeters in diameter have been grown in the laboratory. Experiments are being continued in an effort to produce laser quality crystals of $Ca_3(VO_4)_2$.[16]

Researchers have produced columbium in the form of metallic buttons by a calciothermic reduction of columbium pentoxide using sulfur as the heat booster. The influence of calcium and sulfur content of the charge on the quality and yield of the metal was studied.[17]

The thermal reduction process for the preparation of calcium metal from calcined limestone and aluminum was investigated. Tests were conducted to provide a preliminary indication of the effect of the aluminum reducing agent in the calcium oxide charge upon the calcium metal yield and the reduction efficiency of the aluminum. A greater yield of calcium metal was possible from the higher aluminum content charges, and a critical reduction temperature was necessary to achieve the highest recovery of calcium metal.[18]

A comprehensive report was published describing in detail the vaporization method for the distillation of crude calcium and the fractional distillation technique to produce special high-purity calcium.[19]

The reaction of hydrogen with alloys or intermetallic compounds in which one of the constituents forms a stable hydride and the other does not is a convenient method for obtaining thermodynamic data for many systems. The reaction of hydrogen with the calcium compounds $CaMg_2$ and $CaCu_5$ has been investigated. Thermodynamic data were obtained for this system from the reaction products consisting of the hydride CaH_2 and nearly pure copper and magnesium.[20]

A method of quantitative analysis of samples containing calcium in the presence of magnesium was developed. The calcium is directly titrated with EGTA in the presence of an indicator, which changes color when the end point is reached.[21]

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[14] Chemical Age (London). ICI Calcium Chloride Plant on Stream. V. 92, No. 2359, Sept. 26, 1964, p. 457.

[15] Chemical Engineering. Neutral Chlorine Dioxide Bleaching Gets Tryout in Commercial Pulp Mill. V. 71, No. 20, Sept. 28, 1964, p. 65.

[16] Journal of the Electrochemical Society. Note on Calcium-Orthovanadate. V. 3, No. 7, July 1964, pp. 873–874.

[17] Gupta, C. K., and P. K. Jena. Transactions of the Metallurgical Society of AIME. Calciothermic Reduction of Niobium (Columbium) Pentoxide. V. 230, No. 6, October 1964, pp. 1433–1438.

[18] Mineral Processing. Vacuum Calcination Yields Calcium From Lime-Aluminum Briquette. V. 5, No. 3. March 1964, pp. 27–30.

[19] Journal of Metals. Methods for Producing High-Purity Calcium. V. 16, No. 2, February 1964, pp. 171–174.

[20] Journal of the Less Common Metals (the Netherlands). Reaction of Hydrogen With $CaMg_2$ and $CaCu_5$ and Thermodynamic Properties of the Compounds. V. 7, No. 2, August 1964, pp. 120–126.

A patent was granted for a calcium-bearing inoculant capable of improving the mechanical properties of gray iron. Range of components is given as calcium 1.5 to 4 percent; silicon, 58 to 68 percent; manganese, 9 to 12 percent; barium, 2.5 percent minimum; aluminum, 0.8 to 1.8 percent; and iron, the remainder. Usual addition of the agent to cast iron is 2 to 4 pounds per ton.[22]

Automakers have accelerated their program of studies of materials exposed to calcium chloride and rock salt used for highway deicing purposes in an effort to reduce or eliminate the corrosive action of these salts.[23]

Of special interest was the publication of a report, by the Massachusetts Legislative Research Council, which analyzes State highway deicing practices, economic and cost considerations of chemical deicing, test results of deicing mixtures and the effect of deicers on structures, automobiles, and trees and plant life. It also points out that the minimal side effects created by use of chemicals are far outweighed by the positive results they produce and comments on the savings in time, money, and lives produced each winter by deicing chemicals.[24]

Total savings of bulk over bagged calcium chloride is estimated to be at least $10 per ton. The properties that make calcium chloride an excellent ice melter also make it a sensitive material, so it requires careful storage. The material requires covered storage, and it is suggested keeping these storage tips in mind: Keep chloride dry during delivery and storage; store on well-drained, paved areas; use dry salt for premixing, and store and handle calcium chloride-salt mixtures like calcium chloride.[25]

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[21] Bittner, Donald L. Calcium Determination Method. U.S. Pat. 3,121,613, Feb. 18, 1964.

[22] Mickelson, R. L. (assigned to Vanadium Corp. of America). Inoculating Alloy. U.S. Pat. 3,137,570, June 16, 1964.

[23] Steel. Detroit Faces New Battle Against Rust. V. 154, No. 9, Mar. 2, 1964, pp. 79–80.

[24] Commonwealth of Massachusetts, Legislative Research Council. The Use and Effects of Highway Deicing Salts. January 1965, 80 pp.

[25] Calcium Chloride Institute News. How To Store Bulk Calcium Chloride. V. 14, No. 3, 1964, pp. 6–7.

Cement

By William R. Barton[1]

◆

RECORD production and shipments of cement were reported in 1964 for the second consecutive year. Pacing the growth of the national economy domestic production of, and requirements for, cement were more than 4 percent greater than in 1963.

Portland cement plant capacity at yearend was reported to be 479.6 million 376-pound barrels compared with 477.6 million barrels at the end of 1963. Despite the increased capacity operating levels increased to 76.5 percent compared with 71.5 percent in 1962 and 73.4 percent in 1963. The declining price trend noted since 1960 was essentially halted with average 1964 mill values reported at $3.22 per barrel compared with $3.23 in 1963. The high cost of continued plant modernizations and plant and distribution terminal expansions made price firming an economic necessity for producers. However, continued intense competition in the market-place served to preclude general price increases in 1964.

TABLE 1.—Salient cement statistics

	1955–59 (average)	1960	1961	1962	1963	1964
United States:						
Production[1] thousand 376-pound barrels	324,023	328,719	332,558	345,567	361,235	377,475
Capacity used at portland cement mills[1] percent	81.9	73.5	73.1	71.5	73.4	76.5
Shipments from mills[1] thousand 376-pound barrels	318,130	321,647	329,443	340,770	358,024	375,340
Value[1 2] thousands	$1,003,730	$1,089,134	$1,105,537	$1,129,387	$1,156,890	$1,209,470
Average value[1] per barrel	$3.16	$3.39	$3.36	$3.31	$3.23	$3.22
Stocks Dec. 31: At mills[1] thousand 376-pound barrels	26,149	35,660	36,415	39,003	[r] 39,496	39,212
Imports for consumption do	4,552	4,108	3,621	5,633	4,030	3,633
Exports	1,205	187	286	380	460	713
Consumption, apparent[3] do	321,477	325,567	332,778	346,023	361,594	378,260
World: Production do	1,475,849	[r] 1,856,059	1,954,249	[r] 2,097,652	[r] 2,209,950	[e] 2,374,109

[r] Revised. [e] Estimate.
[1] Excludes Puerto Rico.
[2] Value received f.o.b. mill, excluding cost of containers.
[3] Quantity shipped plus imports minus exports.

LEGISLATION AND GOVERNMENT PROGRAMS

The Federal Trade Commission (FTC) continued its monitoring of the cement industry to prevent mergers and acquisitions which it considered "might substantially lessen competition or tend to create a monopoly." American Cement Corp., consented, without admission of impropriety, to an FTC order to divest itself of M. F. Hickey Corp., a Brooklyn, N.Y. producer of ready mixed concrete. Similarly, Kaiser Cement & Gypsum Corp., was ordered to sell its Olympic Portland Cement Co., plant at Bellingham, Wash. (purchased in 1958). An appeal was pending, but if the firm loses the decision it plans to erect a new plant at Seattle, Wash. A similar decision against Diamond Alkali Co., also had an appeal pending. Actions have been instituted, or were planned, by FTC against several other cement firms. But, pending clear criteria as to what are permissible acquisitions, other companies continued to purchase concrete manufacturing facilities while awaiting FTC clarification. These measures are deemed necessary to maintain market posture of the cement companies and to maintain profit margins in the face of sales competition.

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[1] Commodity specialist, Division of Minerals.

The U.S. Tariff Commission ruled that white cement imported from Japan was being sold at fair prices under the regulations of the Anti-Dumping Act.

Zoning and other local regulations continued to influence industry planning and operations. A district judge in Boulder County, Colo., ruled that land had been improperly rezoned for a cement plant, delaying construction of the plant. Residents of Fairborn, Ohio and Hudson, N.Y., were disgruntled about dust fallout asserted to originate at nearby cement plants. The Texas Parks and Wildlife Commission so restricted dredging operations for shell in Galveston and Trinity Bays that a cement plant was forced to shut down.

Lehigh Portland Cement Co. was refused a tax refund of $1.3 million by a U.S. District Court in Philadelphia. It was ruled that limestone quarried by the company was not chemical grade, and therefore not qualified for the 15 percent depletion allowance accorded such stone.

PORTLAND CEMENT

PRODUCTION AND SHIPMENTS

Four new plants began production in 1964. Nevada Cement Co., Fernley, Nev., opened a 1 million barrel plant, and Oklahoma Cement Co. completed a 1.5 million barrel plant at New Orleans, La. Alpha Portland Cement Co. opened its new 3 million barrel plant at Catskill, N.Y. The Southwestern Portland Cement Co. completed its facility at Bushland, Tex. A plant was under construction at Festus, Mo. (River Cement Co.). Plans were announced to build 8 new production plants. Dundee Cement Co. will build a 7 million barrel plant at Clarksville, Mo., that will employ 200 people and feature a record size 760-foot long kiln. Ideal Cement Co. is planning to build a 2.5 million barrel plant at Seattle, Wash. Puerto Rican Cement Co., Inc. will add a 200,000 barrel white cement facility at Ponce, Puerto Rico. The other 5 projects announced were: Southern California Cement Co., at Gorman, Calif.; Southwestern Portland Cement Co., at an unannounced site in northern Kentucky; Martin-Marietta Corp. (Rocky Mountain Cement Co.), Lyons, Colo.; Lake Ontario Cement Ltd. (Rochester Portland Cement Corp.) near Watertown, N.Y.; and Medusa Portland Cement Co., at Charlevoix, Mich. The plans of National Gypsum Co. for a site at Bellefonte, Pa., have been indefinitely postponed. It was also reported that Alaska Portland Cement, Ltd. of San Francisco has shifted the site of its planned Alaskan plant from Cantwell to a location on the Kenai Peninsula. Major plant expansions or modernizations were completed or essentially completed in 1964 at Crestmore, Calif. (American Cement Corp.); Cementon, Pa. (Whitehall Cement Manufacturing Co.); Kingston, N.Y. (Colonial Sand and Stone Co., Inc.); and Dixon, Ill. (Medusa Portland Cement Co.). Nine major plant expansions or modernizations were either underway or due to begin shortly in 1964: Diamond Portland Cement Co., Middle Branch, Ohio; Marquette Cement Manufacturing Co., Catskill, N.Y.; Universal Atlas Cement Division of United States Steel Corp., Hannibal, Mo.; Bessemer Cement Co., Bessemer, Pa.; Huron Portland Cement Co., Alpena, Mich.; Northwestern States Portland Cement Co., Mason City, Iowa; Arkansas Cement Corp., Foreman, Ark.; Kaiser Cement & Gypsum Corp., Montana City, Mont., and Penn-Dixie Cement Corp., Petosky, Mich.

Alpha Portland Cement Co. announced the closure of obsolete production facilities at Martin's Creek, Pa., and Catskill, N.Y. The capacity was no longer required after completion of the new Alpha plant at Catskill. American Cement Corp. announced it will do the same with some of the older facilities at Crestmore, Calif.; no longer needed after additions at the same location. Lone Star Cement Corp. temporarily closed its Houston, Tex., plant on August 12, due to inadequate availability of clean oystershell. Marquette Cement Manufacturing Co. sold its Howes Cave, N.Y., plant to Penn-Dixie Cement Corp. for an unannounced sum.

The general trend continued toward larger plants and plant components and increased automation to achieve production efficiencies and reduced costs. Descriptions were published of equipment and operations at several newer plants.[2] In addition, a periodical devoted an entire issue to modern process developments in new cement plants of the 1960's.[3] The number of portland cement plants in the United States (including Puerto Rico) in 1964, by size group was:

Estimated annual capacity: Dec. 31, million barrels:	*Number of plants*	*Percent of total capacity*
Less than 1	9	1.5
1 to 2	53	16.0
2 to 3	62	31.3
3 to 4	34	23.4
4 to 5	11	9.7
5 and over	12	18.1
Total	181	100.0

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[2] Bergstrom, J. H. Optimization is Design Criteria at Castle Hayne. Rock Products, Min., and Proc., v. 67, No. 3, March 1964, pp. 53–58.

————. Innovations in Every Department. Rock Products, Min. and Proc., v. 67, No. 4, April 1964, pp. 60–66.

Herod, B. C. Missouri Portland Boosts Capacity of River Plant and Terminal Network. Pit and Quarry, v. 56, No. 9, March 1964, pp. 84–90, 93–95, 145.

Levine, Sidney, Alpha's Catskill Plant Features Advanced Processing Concepts. Rock Products, v. 67, No. 12, December 1964, pp. 52–64, 106, 108.

Mitchell, R. J. Permanente Plant New Montana Bonanza. Rock Products Min. and Proc., v. 67, No. 2, February 1964, pp. 57–62.

Pit and Quarry. Ideal Cement Adds 18th Production Facility. V. 56, No. 8, February 1964, pp. 79–85.

Taeler, D. H. Water Provides *Triple* Benefit. Miner. Proc., v. 5, No. 10, October 1964, pp. 24–26.

Trauffer, W. E. Southern Cement's New Atlanta Plant. Pit and Quarry, v. 57, No. 1, July 1964, pp. 120–133, 174–179.

[3] Rock Products. Min. and Proc., Annual Cement Issue. V. 67, No. 5, May 1964, 204 pp.

TABLE 2.—Finished portland cement produced, shipped, and in stock in the United States,[1] by districts

District	Active plants		Production		Shipments from mills						Stocks at mills Dec. 31	
			Thousand 376-pound barrels		1963			1964			Thousand 376-pound barrels	
						Value			Value			
	1963	1964	1963	1964	Thousand 376-pound barrels	Total (thousands)	Average per barrel	Thousand 376-pound barrels	Total (thousands)	Average per barrel	1963 [2]	1964
New York, Maine	13	13	23,525	27,869	22,999	$69,955	$3.04	28,155	$86,607	$3.08	4,040	3,671
Eastern Pennsylvania	17	16	30,402	29,014	30,513	92,591	3.03	28,861	84,526	2.93	3,992	4,025
Western Pennsylvania	5	5	7,956	8,949	7,803	25,612	3.28	8,802	28,883	3.28	1,667	1,674
Maryland, West Virginia	4	4	10,277	10,686	9,773	30,211	3.09	10,384	32,198	3.10	1,047	1,115
Ohio	10	10	16,300	15,606	16,218	53,244	3.28	15,553	50,647	3.26	2,064	2,079
Michigan	9	9	24,194	26,802	25,016	76,944	3.08	26,745	84,316	3.15	2,532	2,589
Indiana, Kentucky, Wisconsin	8	8	19,155	20,704	18,280	60,266	3.30	19,696	64,114	3.26	2,270	2,441
Illinois	5	4	9,465	9,978	9,281	30,577	3.29	9,790	32,191	3.29	1,284	1,345
Tennessee	6	6	8,660	8,471	8,283	26,760	3.23	8,343	26,791	3.21	916	737
Virginia, North Carolina, South Carolina	5	5	8,561	10,672	8,295	26,294	3.17	10,666	32,428	3.04	1,054	1,060
Georgia, Florida	7	7	11,291	12,028	11,226	36,608	3.26	12,090	39,165	3.24	1,198	1,074
Alabama	8	8	12,611	13,059	12,218	38,417	3.14	12,870	40,108	3.12	1,172	1,025
Louisiana, Mississippi	5	6	8,422	9,049	8,327	26,585	3.19	9,025	28,365	3.14	830	790
Minnesota, South Dakota, Nebraska	4	4	7,883	7,730	7,718	26,110	3.38	7,649	26,516	3.47	1,227	1,279
Iowa	5	5	12,787	13,651	12,495	42,891	3.43	13,607	46,398	3.41	1,479	1,446
Missouri	5	5	12,692	12,399	12,402	41,640	3.36	12,378	42,618	3.44	1,582	1,518
Kansas	6	6	8,248	8,335	8,201	25,372	3.09	8,483	25,959	3.06	1,522	1,358
Oklahoma, Arkansas	6	6	11,299	11,408	11,416	33,508	2.93	11,756	34,641	2.94	1,549	1,160
Texas	16	17	29,150	29,792	29,104	92,734	3.19	30,030	94,492	3.15	2,560	2,304
Wyoming, Montana, Idaho	4	4	3,616	3,659	3,418	11,963	3.50	3,601	12,568	3.49	503	562
Colorado, Arizona, Utah, New Mexico	7	7	13,559	12,838	13,562	45,245	3.34	12,745	43,242	3.39	926	1,018
Oregon, Washington	9	9	7,799	8,244	7,727	27,576	3.57	8,219	29,525	3.59	1,143	1,155
Northern California	6	6	17,973	18,999	18,028	58,839	3.26	18,418	59,834	3.25	1,164	1,745
Southern California	7	7	28,119	28,982	28,250	88,817	3.14	28,786	90,099	3.13	1,553	1,748
Hawaii	2	2	1,428	1,798	1,483	7,125	4.80	1,717	8,877	5.17	139	219
Puerto Rico	2	2	7,171	7,911	7,217	22,090	3.06	7,926	23,879	3.01	180	164
Total	181	181	352,543	368,633	349,253	1,117,974	3.20	[3] 366,304	1,168,987	3.19	39,593	39,301

[1] Includes Puerto Rico.

[2] Incorporates some revisions.

[3] Does not include finished cement used in manufacturing prepared masonry cement as follows: 1963, 2,927,000 barrels; 1964, 2,621,000 barrels.

TABLE 3.—Portland cement produced and shipped in the United States,[1] by types

Type and year	Active plants	Production (thousand 376-pound barrels)	Shipments		
			Thousand 376-pound barrels	Value	
				Total (thousands)	Average per barrel
General use and moderate heat (types I and II):					
1955–59 (average)	164	290,620	285,424	$881,601	$3.09
1960	175	[2] 297,279	290,968	962,453	3.31
1961	174	[2] 302,107	298,616	980,371	3.28
1962	177	[2] 313,888	309,784	1,004,793	3.24
1963	180	[2] 329,929	326,918	1,032,809	3.15
1964	181	[2] 347,954	346,052	1,090,712	3.15
High-early-strength (type III):					
1955–59 (average)	113	12,668	12,354	44,413	3.59
1960	135	[3] 13,961	13,772	51,731	3.76
1961	135	[3] 13,530	14,305	53,000	3.71
1962	141	[3] 14,958	14,597	53,576	3.67
1963	145	[3] 14,592	14,559	51,167	3.51
1964	144	[3] 12,873	12,530	44,124	3.52
Low-heat (type IV):					
1955–59 (average)	2	10	5	21	3.93
1960	3	7	8	32	4.07
1961	2	18	14	60	4.23
1962	2	----------	9	37	4.45
1963	3	----------	----------	----------	----------
1964	1	(4)	(4)	(4)	----------
Sulfate-resisting (type V):					
1955–59 (average)	8	156	149	567	3.80
1960	14	445	435	1,664	3.83
1961	13	931	416	1,608	3.87
1962	11	236	244	1,048	4.29
1963	18	349	324	1,267	3.91
1964	16	446	398	1,443	3.63
Oil-well:					
1955–59 (average)	16	1,467	1,456	5,027	3.45
1960	14	1,055	1,059	3,669	3.46
1961	14	1,015	1,235	4,181	3.39
1962	13	1,281	1,215	4,140	3.41
1963	15	1,239	1,158	3,878	3.35
1964	12	1,347	1,306	4,329	3.31
White:					
1955–59 (average)	4	1,270	1,223	7,604	6.22
1960	4	[5] 1,504	1,384	9,274	6.70
1961	5	[5] 1,647	1,532	10,387	6.78
1962	5	[5] 1,726	1,668	11,690	7.01
1963	5	[5] 2,050	1,935	13,547	7.00
1964	5	[5] 2,139	2,111	14,821	7.02
Portland-slag and portland pozzolan:					
1955–59 (average)	10	4,963	4,909	15,573	3.17
1960	7	[6] 3,630	3,525	12,057	3.42
1961	8	[6] 3,586	3,316	11,179	3.37
1962	7	[6] 2,848	2,868	9,524	3.32
1963	8	[6] 2,470	2,620	8,681	3.31
1964	10	[6] 1,047	1,057	3,656	3.46
Miscellaneous: [7]					
1955–59 (average)	23	1,421	1,212	4,484	3.70
1960	20	[5] 1,128	1,141	4,366	3.83
1961	19	[5] 1,280	1,317	4,992	3.79
1962	19	[5] 1,551	1,438	5,581	3.88
1963	23	[5] 1,914	1,739	6,625	3.81
1964	22	[5] 2,827	2,850	9,902	3.47
Grand total:					
1955–59 (average)	164	312,575	306,732	959,290	3.13
1960	[8] 176	319,009	312,292	1,045,246	3.35
1961	[8] 175	324,114	320,751	1,065,778	3.32
1962	[8] 178	336,488	331,823	1,090,389	3.29
1963	[8] 181	352,543	349,253	1,117,974	3.20
1964	[8] 181	368,633	366,304	1,168,987	3.19

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[1] Includes Puerto Rico.

[2] Includes air-entrained portland cement as follows (in thousand 376-pound barrels): 1960, 35,473; 1961, 36,373; 1962, 38,096; 1963, 40,649; 1964, 43,950.

[3] Includes air-entrained portland cement as follows (in thousand 376-pound barrels): 1960, 4,645; 1961, 4,140; 1962, 5,078; 1963, 4,879; 1964, 2,754.

[4] Less than ½ unit.

[5] Includes a small amount of air-entrained portland cement.

[6] Includes air-entrained portland cement as follows (in thousand 376-pound barrels): 1960, 1,400; 1961, 1,996; 1962, 1,617; 1963. 1,369; 1964, 343.

[7] Includes hydroplastic, plastic, and waterproofed cements.

[8] Includes number of plants making air-entrained portland cement as follows: 1960, 120; 1961, 120; 1962, 121; 1963, 121; 1964, 130.

TABLE 4.—Portland-cement-manufacturing capacity of the United States,[1] by districts

District	Capacity Dec. 31 (thousand 376-pound barrels)		Percent utilized	
	1963	1964	1963	1964
New York, Maine	37,126	39,776	63.4	70.1
Eastern Pennsylvania	42,161	40,186	72.1	72.2
Western Pennsylvania	11,708	12,208	68.0	73.3
Maryland, West Virginia	11,880	11,880	86.5	89.9
Ohio	22,400	22,400	72.8	69.7
Michigan	34,154	32,654	70.8	82.1
Indiana, Kentucky, Wisconsin	26,591	25,327	72.0	81.7
Illinois	13,930	11,950	67.9	83.5
Tennessee	9,974	10,194	86.8	83.1
Virginia, North Carolina, South Carolina	14,110	14,110	60.7	75.6
Georgia, Florida	20,072	20,427	56.3	58.9
Alabama	16,260	16,140	77.6	80.9
Louisiana, Mississippi	9,500	11,275	88.7	80.3
Minnesota, South Dakota, Nebraska	9,326	9,117	84.5	84.8
Iowa	15,610	15,630	81.9	87.3
Missouri	15,805	16,043	80.3	77.3
Kansas	12,364	13,106	66.7	63.6
Oklahoma, Arkansas	14,225	15,184	79.4	75.1
Texas	42,289	43,160	68.9	69.0
Wyoming, Montana, Idaho	4,700	5,100	76.9	71.7
Colorado, Arizona, Utah, New Mexico	16,600	15,750	81.7	81.5
Oregon, Washington	10,750	10,750	72.5	76.7
Northern California	20,850	21,150	86.2	89.8
Southern California	35,400	35,400	79.4	81.9
Hawaii	2,700	2,700	52.9	66.6
Puerto Rico	7,100	8,001	101.0	98.9
Total	477,585	479,618	73.8	76.9

[1] Includes Puerto Rico.

TABLE 5.—Capacity of portland cement plants in the United States,[1] by processes

Process	Capacity, Dec. 31						Percent of capacity utilized			Percent of total finished cement produced		
	Thousand 376-pound barrels			Percent of total								
	1962	1963	1964	1962	1963	1964	1962	1963	1964	1962	1963	1964
Wet	275,933	284,601	294,767	58.8	59.6	61.5	70.9	74.0	75.7	58.2	59.8	60.5
Dry	193,041	192,984	184,851	41.2	40.4	38.5	72.9	73.5	78.7	41.8	40.2	39.5
Total	468,974	477,585	479,618	100.0	100.0	100.0	71.8	73.8	76.9	100.0	100.0	100.0

[1] Includes Puerto Rico.

TABLE 6.—Portland cement clinker produced and in stock at mills in the United States,[1] by process[2]

Clinker	Number of plants		Thousand 376-pound barrels			
			Production		Stocks on Dec. 31—	
	1963	1964	1963	1964	1963[r]	1964[p]
Wet	107	110	208,410	218,141	8,967	8,773
Dry	72	71	145,836	154,029	7,826	9,959
Total	179	181	354,246	372,170	16,793	18,732

[r] Revised. [p] Preliminary.
[1] Includes Puerto Rico.
[2] Compiled from monthly estimates of producers.

TABLE 7.—Production of portland-cement clinker at mills in the United States[1] in 1964, by months and districts

(Thousand 376-pound barrels)

District	January	February	March	April	May	June	July	August	September	October	November	December
New York, Maine	1,899	1,555	1,441	2,168	2,683	2,549	2,583	2,556	2,799	2,763	2,619	2,194
Eastern Pennsylvania	2,315	1,850	2,141	2,588	2,842	2,698	2,648	2,694	2,864	2,848	2,419	2,164
Western Pennsylvania	90	199	583	741	901	832	922	903	948	883	781	755
Maryland, West Virginia	802	661	840	854	896	992	1,040	1,035	963	1,013	984	986
Ohio	984	1,031	1,167	1,338	1,419	1,348	1,650	1,558	1,524	1,478	1,379	980
Michigan	1,857	1,912	2,254	2,191	2,540	2,469	2,554	2,446	2,480	2,430	2,387	2,315
Indiana, Kentucky, Wisconsin	1,270	1,321	1,535	1,821	1,781	1,838	1,919	1,908	2,000	2,040	1,758	1,534
Illinois	616	604	872	965	783	873	918	980	919	916	823	860
Tennessee	544	430	719	765	736	758	838	831	778	803	691	792
Virginia, North Carolina, South Carolina	670	678	992	937	934	883	1,021	994	995	1,028	932	1,071
Georgia, Florida	655	789	1,164	1,141	1,287	1,081	1,214	1,128	890	819	986	990
Alabama	757	789	1,100	1,157	1,180	1,250	1,206	1,152	1,189	1,152	1,107	1,164
Louisiana, Mississippi	539	602	519	528	679	785	786	819	918	868	902	749
Minnesota, South Dakota, Nebraska	440	476	600	655	790	687	754	754	724	773	674	521
Iowa	852	947	767	1,093	1,171	1,330	1,330	1,272	1,268	1,292	1,207	1,019
Missouri	601	736	910	982	1,132	1,178	1,108	1,114	1,162	1,219	1,148	1,129
Kansas	313	361	665	750	885	833	909	918	769	837	756	521
Oklahoma, Arkansas	790	877	1,005	929	1,010	1,113	1,031	1,002	1,022	916	1,013	1,082
Texas	1,776	2,023	2,435	2,664	2,755	2,871	2,782	2,779	2,577	2,707	2,423	2,042
Wyoming, Montana, Idaho	199	199	366	377	391	359	363	381	371	336	281	219
Colorado, Arizona, Utah, New Mexico	1,032	947	1,091	1,177	1,218	1,154	1,206	1,133	1,115	1,140	1,095	[2] 1,127
Oregon, Washington	526	564	548	646	742	771	779	767	749	750	677	578
Northern California	1,491	1,319	1,632	1,665	1,635	1,780	1,711	1,679	1,526	1,382	1,326	1,371
Southern California	2,225	2,241	2,370	2,388	2,484	2,663	2,703	2,647	2,363	2,519	2,304	2,411
Hawaii	----------	128	201	150	160	183	192	171	159	188	136	118
Puerto Rico	631	535	624	546	601	624	688	665	593	576	609	637
Total:												
1964	23,874	23,774	28,541	31,216	33,635	33,902	34,855	34,286	33,665	33,676	31,417	29,329
1963	22,784	20,574	25,278	29,554	32,975	32,518	33,880	33,618	32,245	33,049	30,737	27,034

[1] Includes Puerto Rico.
[2] Includes a small amount from the Nevada plant.

TABLE 8.—Production and percentage of total output of portland cement in the United States,[1] by raw materials used

Year	Cement rock and pure limestone		Limestone and clay or shale [2] [3]		Blast-furnace slag and limestone	
	Thousand 376-pound barrels	Percent	Thousand 376-pound barrels	Percent	Thousand 376-pound barrels	Percent
1955–59 (average)	72,168	23.1	221,057	70.7	19,351	6.2
1960	85,924	26.9	215,625	67.6	17,460	5.5
1961	70,824	21.9	230,376	71.1	22,914	7.0
1962	75,042	22.3	238,160	70.7	23,286	7.0
1963	85,741	24.3	251,068	71.2	15,734	4.5
1964	85,884	23.3	260,376	70.6	22,373	6.1

[1] Includes Puerto Rico.
[2] Includes output of 4 plants using marl and clay in 1955–59 (average); 4 plants in 1959–60; 3 plants in 1961; 1 plant in 1963; 1 plant using marl only in 1963; and 2 plants in 1962 and 1964.
[3] Includes output of 8 plants using oystershells and clay in 1955–59 (average); 9 plants in 1959–61; 10 plants in 1962; 11 plants in 1963; and 12 plants in 1964.

TABLE 9.—Raw materials used in producing portland cement in the United States[1]

(Thousand short tons)

Raw materials	1962	1963	1964
Cement rock	20,829	17,354	18,853
Limestone (including oystershell)	69,456	77,663	80,759
Marl	1,689	452	391
Clay and shale [2]	9,943	10,650	11,593
Blast-furnace slag	1,119	1,040	950
Gypsum	2,826	2,929	3,299
Sand and sandstone (including silica and quartz)	1,423	1,811	1,376
Iron materials [3]	659	572	617
Miscellaneous [4]	105	200	84
Total	108,049	112,671	117,922

[1] Includes Puerto Rico.
[2] Includes fuller's earth, diaspore, and kaolin.
[3] Includes iron ore, pyrite cinders and ore, and mill scale.
[4] Includes fluorspar, pumicite, calcium chloride, soda ash, borax, staurolite, air-entraining compounds, and grinding aids.

TABLE 10.—Finished portland cement produced and fuel consumed by the portland-cement industry in the United States,[1] by processes

Year and process	Finished cement produced			Fuel consumed		
	Plants	Thousand 376-pound barrels	Percent of total	Coal (thousand short tons)	Oil (thousand 42-gallon barrels)	Natural gas (thousand cubic feet)
1963:						
Wet	110	210,678	59.8	4,492	3,560	134,426,751
Dry	71	141,865	40.2	3,830	466	63,961,585
Total	181	352,543	100.0	[2] 8,322	4,026	[3] 198,388,336
1964:						
Wet	115	223,077	60.5	4,644	3,484	137,099,330
Dry	66	145,556	39.5	[4] 4,180	818	64,573,144
Total	181	368,633	100.0	[5] 8,824	4,302	[6] 201,672,474

[1] Includes Puerto Rico.
[2] Comprises 183,899 tons of anthracite and 8,138,439 tons of bituminous coal.
[3] Includes 125,183 thousand cubic feet of coke-oven gas.
[4] Excludes 7,644 tons coal Riverton Lime & Stone Co., Inc., Va.—masonry only—no portland cement.
[5] Comprises 152,595 tons of anthracite and 8,671,122 tons of bituminous coal.
[6] Includes 263,707 thousand cubic feet of coke-oven gas.

TABLE 11.—Portland cement produced in the United States,[1] by kinds of fuel

Year and fuel	Finished cement produced: Plants	Finished cement produced: Thousand 376-pound barrels	Finished cement produced: Percent of total	Fuel consumed: Coal (thousand short tons)	Fuel consumed: Oil (thousand 42-gallon barrels)	Fuel consumed: Natural gas (thousand cubic feet)
1963:						
Coal	57	[2] 106,921	30.3	5,339		
Oil	9	[2] 15,427	4.4		2,757	
Natural gas	38	[2] 72,132	20.5			89,351,368
Coal and oil	20	42,743	12.1	1,718	760	
Coal and natural gas	30	50,179	14.2	997		[3] 39,034,618
Oil and natural gas	18	47,662	13.5		463	55,886,421
Coal, oil, and natural gas	9	17,479	5.0	268	46	14,115,929
Total	181	352,543	100.0	[4] 8,322	4,026	198,388,336
1964:						
Coal	59	[2] 123,203	33.4	5,981		
Oil	8	[2] 16,273	4.4		2,870	
Natural gas	44	[2] 73,431	19.9			88,937,219
Coal and oil	18	38,998	10.6	1,661	761	
Coal and natural gas	27	50,954	13.8	1,085		[5] 39,172,137
Oil and natural gas	18	52,819	14.4		651	58,853,368
Coal, oil, and natural gas	7	12,955	3.5	97	20	14,709,750
Total	181	368,633	100.0	[6] 8,824	4,302	201,672,474

[1] Includes Puerto Rico.

[2] Average consumption of fuel per barrel of cement produced as follows: 1963—coal, 99.9 pounds; oil, 0.1787 barrel; natural gas, 1,239 cubic feet; 1964—coal, 97.1 pounds; oil, 0.1764 barrel; natural gas, 1,211 cubic feet.

[3] Includes 125,183 thousand cubic feet of coke-oven gas.

[4] Comprises 183,899 tons of anthracite and 8,138,439 tons of bituminous coal.

[5] Includes 263,707 thousand cubic feet of coke-oven gas.

[6] Comprises 152,595 tons of anthracite and 8,671,122 tons of bituminous coal.

TABLE 12.—Electric energy used at portland cement plants in the United States,[1] by processes

Year and process	Electric energy used: Generated at portland cement plants: Active plants	Generated at portland cement plants: Million kilowatt-hours	Purchased: Active plants	Purchased: Million kilowatt-hours	Total: Million kilowatt-hours	Total: Percent	Finished cement produced (thousand 376-pound barrels)	Average electric energy used per barrel of cement produced (kilowatt-hours)
1963:								
Wet	20	471	108	4,271	4,742	57.7	210,678	22.5
Dry	23	1,059	68	2,413	3,472	42.3	141,865	24.5
Total	43	1,530	176	6,684	8,214	100.0	352,543	23.2
Percent of total electric energy used		18.6		81.4	100.0			
1964:								
Wet	22	466	111	4,635	5,101	58.0	223,077	22.9
Dry	20	1,074	69	2,620	3,694	42.0	145,556	25.4
Total	42	1,540	180	7,255	8,795	100.0	368,633	23.8
Percent of total electric energy used		17.5		82.5	100.0			

[1] Includes Puerto Rico.

TABLE 13.—Shipments of portland cement from mills in the United States,[1] in bulk and in containers by types of carriers

Year and type of carrier	In bulk		In paper bags [2]		Total shipments	
	Thousand 376-pound barrels	Percent	Thousand 376-pound barrels	Percent	Thousand 376-pound barrels	Percent
1963:						
Truck	187,723	62.6	34,958	70.7	222,681	63.8
Railroad	103,113	34.4	14,228	28.8	117,341	33.6
Boat	8,700	2.9	144	.3	8,844	2.5
Used at the plant	260	.1	127	.2	387	.1
Total	299,796	100.0	49,457	100.0	349,253	100.0
Percent of total	85.8	----------	14.2	----------	100.0	----------
1964:						
Truck	206,714	64.4	34,754	76.5	241,468	65.9
Railroad	106,425	33.2	10,316	22.7	116,741	31.9
Boat	7,349	2.3	302	.7	7,651	2.1
Used at the plant	386	.1	58	.1	444	.1
Total	320,874	100.0	45,430	100.0	366,304	100.0
Percent of total	87.6	----------	12.4	----------	100.0	----------

[1] Includes Puerto Rico.

[2] Cloth bags and other containers included with paper bags to avoid disclosing individual company confidential data.

TRANSPORTATION

Construction of modern, automated market center distribution terminals for storage and transshipment of cement continued. Such facilities, costing $100,000 to $2 million, expedite service to customers and have become a competitive necessity. Among new or expanded distribution terminals opened, under construction, or planned in 1964 were: Decatur, Ala. (Missouri); Mobile, Ala. (Lone Star); Palm Beach, Fla. (Ideal); Jacksonville; Fla. (Universal-Atlas); Idaho Falls, Idaho (Idaho); Boise, Idaho (Oregon); Twin Falls, Idaho (Idaho); Pocatello, Idaho (Idaho and Kaiser); Meridian, Idaho (Kaiser); Waukegan, Ill. (Universal-Atlas); Indianapolis, Ind. (Dundee); Bettendorf, Iowa (Universal-Atlas); Bloomington, Minn. (Marquette); Ithaca, N.Y. (Rochester); Fargo, N. Dak. (Lehigh and Northwestern States); Cincinnati, Ohio (River); Portland, Oreg. (Calaveras and Kaiser); Creighton, Pa. (Columbia); and Lubbock, Tex. (Universal-Atlas). Atlantic Cement Co., Inc. regrouped its distribution network by selling its terminal at Tampa, Fla., to General Portland Cement Co. It also leased the bulk of a Brooklyn, N.Y., terminal from Triangle Cement Co., and purchased a 30,000 barrel automated cement barge from the same company.

TABLE 14.—Destination of shipments of all types of finished portland and high-early-strength cement from mills in the United States, by States

(Thousand 376-pound barrels)

Destination	Finished portland		High-early-strength	
	1963	1964	1963	1964
Alabama	4,905	6,216	60	56
Alaska [1]	W	W	W	W
Arizona	4,622	4,313	W	W
Arkansas	3,556	3,807	27	40
Northern California	15,883	17,141	208	42
Southern California	26,435	26,874	40	184
Colorado	4,763	4,355	27	19
Connecticut [1]	3,823	4,695	377	286
Delaware [1]	1,135	881	87	36
District of Columbia [1]	1,520	1,647	87	82
Florida	[2] 12,546	[2] 13,035	692	687
Georgia	7,930	8,660	88	141
Hawaii	995	1,296		
Idaho	1,141	1,141	15	29
Illinois	16,838	18,528	624	621
Indiana	8,675	10,033	424	430
Iowa	6,827	7,629	213	181
Kansas	5,024	5,132	63	58
Kentucky	5,818	4,234	156	156
Louisiana	9,112	10,405	108	104
Maine	816	926	87	82
Maryland	6,412	7,284	399	220
Massachusetts [1]	5,356	6,126	586	370
Michigan	15,519	15,569	745	971
Minnesota	6,533	6,894	370	417
Mississippi	3,999	4,108	17	15
Missouri	8,990	10,266	282	284
Montana	1,498	1,613	17	13
Nebraska	4,957	4,460	206	194
Nevada [1]	2,090	1,807	19	17
New Hampshire [1]	727	733	90	97
New Jersey [1]	9,410	9,507	1,576	546
New Mexico	2,911	2,759	200	260
New York	18,260	18,137	1,440	990
North Carolina	5,742	6,175	160	194
North Dakota	1,523	1,895	29	38
Ohio	17,518	18,456	551	593
Oklahoma	7,105	6,163	22	28
Oregon	3,189	3,055	91	95
Eastern Pennsylvania	9,676	9,869	1,023	501
Western Pennsylvania	5,640	5,979	186	268
Rhode Island [1]	880	885	87	73
South Carolina	2,705	2,998	37	39
South Dakota	1,411	1,578	69	48
Tennessee	6,228	6,727	144	157
Texas	24,618	26,156	1,417	1,493
Utah	2,509	2,529	66	65
Vermont [1]	435	464	33	23
Virginia	7,947	8,418	449	419
Washington	5,224	5,368	480	435
West Virginia	1,896	2,160	46	40
Wisconsin	8,599	8,402	291	313
Wyoming	1,190	1,273	4	2
Total United States	343,061	358,761	14,515	12,452
Other countries	[3] 6,192	[3] 7,543	[4] 44	[4] 77
Total shipped from cement plants	349,253	366,304	14,559	12,529

W Withheld to avoid disclosing individual company confidential data; included with "Other countries."

[1] Noncement producer.

[2] Includes shipments from Puerto Rican mills.

[3] Direct shipments by producers to foreign countries, the State of Alaska, and to Puerto Rico, including distribution from Puerto Rican mills.

[4] Direct shipments by producers to other countries and the States of Alaska and Arizona.

CONSUMPTION

Precasting of concrete building components weighing several tons continued to gain in practice. Among increasingly accepted and used factory-made innovations were prestressed-precast beams, spans, and panels, unitized precast fireplaces and chimneys with exterior faces simulating brick, stone, or stucco, and precast exposed-aggregate surfaced units with windows preglazed into the panels. The accelerating trend toward the industrialization of construction, with its innovations, factory processing, and implications, was discussed in some detail in a Stanton Walker lecture.[4] The use of soil cement as facing in an 120-foot high earth dam in Nebraska was described.[5] It saved hauling rock 200 miles for a riprap facing. A total of 52,000 cubic yards of soil cement were emplaced on the project. A paper was published which included a cost analysis of portland cement concrete versus blacktop streets in Akron, Ohio.[6] Based on a projected life of 21 years, the annual road cost per mile was calculated to be $1,248 for concrete versus $1,585 for blacktop.

A number of concrete structures have suffered from cracking and deep spalling from the corrosion of improperly used, embedded alumi-

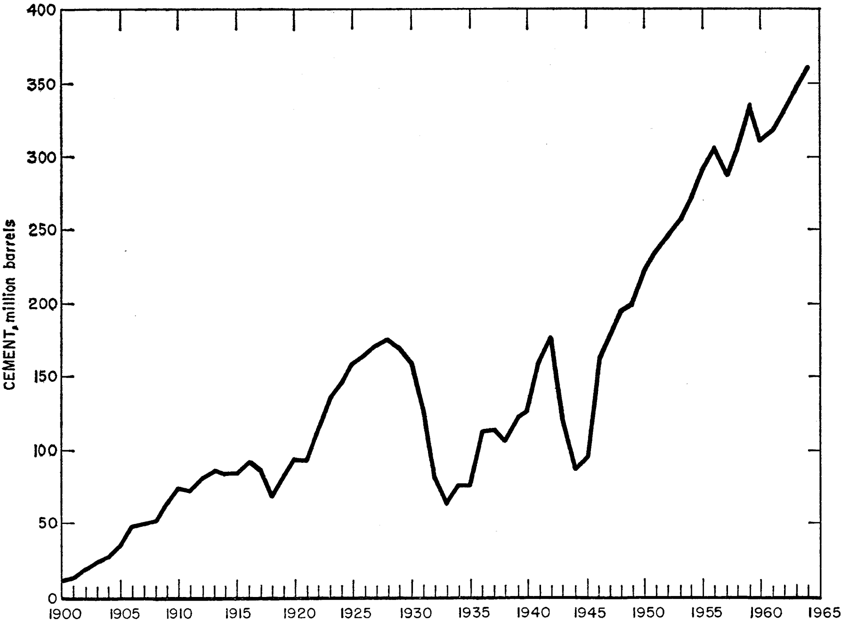

FIGURE 1.—Apparent consumption of finished portland cement in the United States.

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[4] Bates, A. A. Composites in Construction. Stanton Walker Lecture Series on the Materials Sciences. Presented at the University of Maryland, College Park, Md., Nov. 20, 1963. Reprinted in pamphlet form by the University of Maryland Structural Materials Research Laboratory, May 1964, 15 pp.

[5] Construction Methods and Equipment. Soil Cement Subs for Riprap as Facing for Dam. V. 46, No. 1, January 1964, pp. 88-89.

[6] Blaha, W. J. Anatomy of a Street Promotion. Concrete Products. V. 67, No. 6, June 1964, pp. 40-42, 44.

num conduit. The two-year-old District of Columbia Stadium was a highly publicized example, pocked by hundreds of cracks and holes in corridors, walks, and ceilings, where the concrete was deteriorating. Structural soundness was not affected but the condition was hazardous to people walking and generated costly repairs. The corrosion may be caused by galvanic action between aluminum and reinforcing steel, by stray electric currents, or by the reaction between the aluminum and alkalies present in the concrete. Some groups, feeling that protective coatings or coverings on the aluminum could not be relied upon to guarantee a trouble-free structure, banned the use of embedded aluminum conduit in future concrete work.[7]

A handbook of inplace soil stabilization practice using cement, lime, or asphalt was published.[8]

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[7] Bloem, D. L. Corrosion of Aluminum in Concrete. National Ready Mixed Concrete Association, Tech. Inf. Letter No. 208, May 20, 1964, p. 4.

[8] Williamson, A. O. Handbook of In-Place Soil Stabilization, Bros. Inc., Minneapolis, Minn., 1964, 48 pp.

TABLE 15.—Cement shipments by types of customers in 1964

(Quantities in thousand 376-pound barrels)

District	Number of plants in district	Building material dealers		Concrete product manufacturers		Ready-mixed concrete		Highway contractors		Other contractors		Federal, State and other Government agencies		Miscellaneous including own use		Total
		Percent	Quantity	Percent	Quantity	Percent	Quantity	Percent	Quantity	Percent	Quantity	Percent	Quantity	Percent	Quantity	
New York, Maine	13	9.2	2,594	11.5	3,233	65.8	18,515	8.2	2,305	2.5	705	0.1	41	2.7	762	28,155
Eastern Pennsylvania	16	13.7	3,954	21.8	6,294	57.9	16,709	4.8	1,384	.5	143	------	13	1.3	364	28,861
Western Pennsylvania	5	7.7	675	13.9	1,221	60.1	5,288	13.0	1,140	5.0	445	------	2	.3	31	8,802
Maryland, West Virginia	4	5.9	616	18.0	1,872	61.1	6,336	12.2	1,262	2.5	262	.2	23	.1	13	10,384
Ohio	10	8.8	1,377	15.5	2,406	58.5	9,092	16.5	2,563	.2	32	.2	32	.3	51	15,553
Michigan	9	8.0	2,155	13.5	3,620	56.4	15,076	15.5	4,143	3.5	943	.1	21	3.0	787	26,745
Indiana, Kentucky, Wisconsin	8	6.4	1,259	13.2	2,607	66.6	13,108	10.2	1,999	2.7	538	.1	19	.8	166	19,696
Illinois	4	5.3	519	15.7	1,536	66.2	6,479	12.0	1,177	.8	79	------	----------	------	----------	9,790
Tennessee	6	6.6	549	17.7	1,475	59.8	4,991	10.8	904	2.7	229	2.0	160	.4	35	8,343
Virginia, North Carolina, South Carolina	5	5.8	623	18.4	1,959	61.5	6,561	13.1	1,394	.5	52	.3	34	.4	43	10,666
Georgia, Florida	7	12.4	1,504	22.0	2,655	49.8	6,019	11.0	1,327	1.8	221	1.9	232	1.1	132	12,090
Alabama	8	7.0	901	14.1	1,809	57.5	7,400	15.2	1,958	2.6	334	1.4	180	2.2	288	12,870
Louisiana, Mississippi	6	4.4	395	8.6	781	54.2	4,888	16.2	1,459	1.9	170	.1	9	14.6	1,323	9,025
Minnesota, South Dakota, Nebraska	4	12.3	939	7.2	552	38.9	2,973	31.6	2,420	9.8	751	.1	8	.1	6	7,649
Iowa	5	9.8	1,330	16.9	2,300	50.5	6,875	21.5	2,929	1.0	128	.3	42	------	3	13,607
Missouri	5	7.2	887	34.8	4,305	36.2	4,486	19.6	2,429	2.0	246	------	6	.2	19	12,378
Kansas	6	10.1	860	6.6	558	59.6	5,056	17.6	1,496	1.8	155	.3	25	4.0	333	8,483
Oklahoma, Arkansas	6	9.8	1,155	7.1	835	50.6	5,953	23.6	2,769	5.2	612	.2	27	3.5	414	11,765
Texas	17	8.4	2,517	9.4	2,811	60.1	18,058	10.8	3,235	2.4	730	2.8	852	6.1	1,827	30,030
Wyoming, Montana, Idaho	4	7.7	276	6.8	246	48.6	1,752	16.5	593	15.6	561	.1	4	4.7	169	3,601
Colorado, Arizona, Utah, New Mexico	7	10.4	1,328	11.1	1,412	64.1	8,168	7.1	902	4.1	521	.2	30	3.0	384	12,745
Oregon, Washington	9	6.0	492	11.8	973	62.9	5,168	9.7	800	8.8	724	.6	47	.2	15	8,219
Northern California	6	7.9	1,463	7.7	1,415	64.7	11,912	6.6	1,210	12.3	2,270	.4	83	.4	65	18,418
Southern California	7	13.1	3,773	11.1	3,191	66.6	19,167	4.3	1,247	4.3	1,250	.3	73	.3	85	28,786
Hawaii	2	14.3	245	6.9	119	52.1	894	------	----------	7.1	123	19.6	336	------	(1)	1,717
Puerto Rico	2	------	----------	------	----------	57.5	4,556	------	----------	------	----------	------	----------	42.5	3,370	7,926
Total	181	8.8	32,386	13.7	50,185	58.8	215,480	11.8	43,045	3.3	12,224	0.6	2,299	3.0	10,685	366,304

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[1] Less than ½ unit.

STOCKS

TABLE 16.—Stocks of finished portland cement and portland-cement clinker at mills in the United States, [1] on Dec. 31 and yearly range in end-of-month-stocks

(Thousand 376-pound barrels)

Year		Dec. 31, quantity	Range			
			Low		High	
			End of month	Quantity	End of month	Quantity
1960	Cement	35,640	October	28,841	May	40,101
	Clinker	20,958	November	16,838	April	33,616
1961	Cement	36,579	October	28,437	do	39,999
	Clinker	19,516	do	16,215	do	32,432
1962	Cement	39,151	do	29,901	February	40,626
	Clinker	17,922	November	15,051	March	32,950
1963	Cement	[r]39,592	October	28,485	do	42,333
	Clinker	[r]16,793	do	13,631	April	31,908
1964	Cement	39,301	do	30,341	do	45,462
	Clinker	18,732	do	15,331	do	30,713

[r] Revised.

[1] Includes Puerto Rico.

PREPARED MASONRY CEMENTS

TABLE 17.—Shipments of prepared masonry cement from mills in the United States, by States

(Thousand 280-pound barrels)

Destination	1963	1964
Alabama	586	664
Alaska [1]	W	W
Arizona	W	W
Arkansas	332	350
Southern California	----------	11
Colorado	243	219
Connecticut [1]	117	137
Delaware [1]	53	59
District of Columbia [1]	335	410
Florida	1,171	1,235
Georgia	1,166	1,265
Hawaii	----------	----------
Idaho	12	11
Illinois	659	678
Indiana	699	723
Iowa	183	201
Kansas	192	180
Kentucky	548	595
Louisiana	322	363
Maine	69	73
Maryland	610	744
Massachusetts [1]	270	288
Michigan	1,187	1,369
Minnesota	391	409
Mississippi	329	353
Missouri	215	222
Montana	20	24
Nebraska	92	87
Nevada	----------	W
New Hampshire [1]	69	72
New Jersey [1]	576	652
New Mexico	129	109
New York	1,058	1,068
North Carolina	1,464	1,563
North Dakota [1]	59	56
Ohio	1,438	1,451
Oklahoma	322	321
Oregon	1	1
Eastern Pennsylvania	484	554
Western Pennsylvania	558	615
Puerto Rico	----------	W
Rhode Island [1]	29	29
South Carolina	752	807
South Dakota	56	54
Tennessee	995	1,071
Texas	945	926
Utah	12	11
Vermont [1]	36	40
Virginia	1,280	1,338
Washington	42	43
West Virginia	212	234
Wisconsin	493	504
Wyoming	19	18
Total United States	20,830	22,207
Other countries [2]	167	190
Total shipped from cement plants	20,997	22,397

W Withheld to avoid disclosing individual company confidential data; included with "Other countries.

[1] Noncement producer.

[2] Direct shipments by producers to other countries and to Alaska, Arizona, Nevada, and Puerto Rico.

TABLE 18.—Prepared masonry cement produced and shipped in the United States, by districts

District	Active plants		Production (thousand 280-pound barrels)		Shipments from mills					
	1963	1964	1963	1964	1963			1964		
					Thousand 280-pound barrels	Value (thousands)	Average per barrel	Thousand 280-pound barrels	Value (thousands)	Average per barrel
New York, Maine	12	11	1,183	1,102	1,083	$2,798	$2.59	1,154	$2,918	$2.53
Eastern Pennsylvania	15	15	1,611	1,766	1,676	4,257	2.54	1,918	4,868	2.54
Western Pennsylvania	5	5	842	904	834	2,354	2.82	900	2,727	3.03
Maryland, West Virginia	5	5	1,023	1,199	1,084	2,733	2.52	1,207	3,046	2.52
Ohio	8	8	1,072	1,040	1,023	3,084	3.02	1,068	3,127	2.93
Michigan	6	6	1,515	1,889	1,684	4,519	2.68	1,865	4,954	2.66
Indiana, Kentucky, Wisconsin	7	7	2,886	3,061	2,880	7,668	2.66	3,068	8,170	2.66
Illinois	5	4	396	593	472	1,440	3.05	596	2,038	3.42
Tennessee	5	5	1,157	1,209	1,161	3,079	2.65	1,212	3,228	2.66
Virginia, North Carolina, South Carolina	4	5	1,574	1,754	1,588	4,660	2.94	1,734	5,074	2.93
Georgia, Florida	5	5	1,011	1,007	1,049	3,177	3.03	1,042	2,952	2.83
Alabama	9	9	2,475	2,513	2,386	7,242	3.04	2,574	7,794	3.03
Louisiana, Mississippi	4	4	419	438	350	922	2.63	386	1,018	2.64
Minnesota, South Dakota, Nebraska	4	4	224	284	287	913	3.18	277	874	3.16
Iowa	4	4	490	605	551	1,754	3.18	585	1,847	3.15
Missouri	5	5	519	322	417	1,345	3.22	334	1,046	3.13
Kansas	7	7	404	377	387	1,183	3.05	384	1,173	3.05
Oklahoma, Arkansas	5	5	586	582	558	1,617	2.90	575	1,675	2.91
Texas	14	12	837	897	930	2,858	3.07	930	2,805	3.02
Wyoming, Montana, Idaho	3	W	39	W	33	116	3.45	W	W	W
Colorado, Arizona, Utah, New Mexico	5	5	506	507	510	1,714	3.36	497	1,676	3.37
Oregon, Washington	6	W	54	W	54	166	3.08	W	W	W
Undistributed		7		78				91	295	3.24
Total	143	138	20,823	22,127	20,997	59,599	2.84	22,397	63,305	2.83

W Withheld to avoid disclosing individual company confidential data; included with "Undistributed."

NATURAL AND SLAG CEMENTS

Natural cement was produced at two plants, and slag cement was produced at two others. These four plants reported an annual capacity of approximately 1 million barrels.

Because masonry cements prepared at these plants contained some portland cement, they are included in the tabulations of masonry cements prepared at portland cement plants (tables 17 and 18). Production figures from 1957 to 1964 are not strictly comparable with those of earlier years because of changes in methods of reporting by some producers.

TABLE 19.—Natural, slag, and hydraulic-lime cements produced, shipped, and in stock at mills in the United States

Year	Production		Shipments		Stocks Dec. 31 thousand 376-pound barrels
	Active plants	Thousand 376-pound barrels	Thousand 376-pound barrels	Value (thousands)	
1955-59 (average)	5	732	725	$2,344	86
1960	4	568	548	1,949	85
1961	4	225	269	968	40
1962	4	440	402	1,611	78
1963	4	357	352	1,407	83
1964	4	275	283	1,057	76

PRICES

The average value of cement shipments in 1964 largely ended the declining trend of the past several years. Average net value of shipments from all cement plants was $3.22 per barrel, compared with $3.23 in 1963.

Portland cement values at plant changed from $3.17 per barrel in the last quarter of 1963 to $3.19 per barrel in the first quarter of 1964 and by the fourth quarter were down to $3.16. The average value of types I and II cement was $3.13 in the fourth quarter of 1963, $3.14 in the first quarter of 1964, and $3.11 in the fourth quarter of 1964. Type III cement was valued at $3.48 in the fourth quarter of 1963, $3.50 in the first quarter of 1964, and $3.50 in the fourth quarter of 1964. The average price of prepared masonry cement in 280-pound barrels was $2.83 in the fourth quarter of 1963, $2.83 in the first quarter of 1964, and $2.81 in the fourth quarter of 1964. The average value of natural, slag, and hydraulic-lime cement shipments was $3.74 in 1964 compared with $3.99 a barrel in 1963.

Engineering News-Record gives f.o.b. base prices per barrel for portland cement in carload lots in 20 cities across the Nation. In bulk, during 1964, cement sold for an average of $3.96 and ranged from a high of $4.95 in Pittsburgh to a low of $3.39 in Detroit. In paper bags, during 1964, the average price quoted was $4.60 and ranged from a high of $5.65 in Pittsburgh to a low of $3.89 in Detroit. Mortar cement sold for an average $4.20 a barrel and ranged from a high of $4.75 in Los Angeles to a low of $3.04 in Detroit.

TABLE 20.—Average mill value in bulk, of cement in the United States [1]

(Per barrel)

Year	Portland cement [2]	Natural, slag, and hydraulic-lime cements [2]	Prepared masonry cement [3] [4]	All classes of cement [5]
1955–59 (average)	$3.13	$3.23	$2.75	$3.15
1960	3.35	3.56	2.95	3.37
1961	3.32	3.60	2.89	3.35
1962	3.29	4.01	2.87	3.31
1963	3.20	3.99	2.84	3.23
1964	3.19	3.74	2.83	3.22

[1] Includes Puerto Rico.
[2] 376-pound barrels.
[3] Includes masonry cements made at portland, natural, and slag cement plants.
[4] 280-pound barrels.
[5] Includes masonry cement converted to 376-pound barrels.

FOREIGN TRADE

For the third consecutive year imports declined while exports increased. However, imports were still much higher than total exports. A higher import figure is anticipated for 1965 due to a new cement plant in the Bahama Islands.

TABLE 21.—U.S. imports for consumption of cement

(Thousand 376-pound barrels and thousand dollars)

Year	Roman, portland, and other hydraulic cement		Hydraulic cement clinker		White nonstaining portland cement		Total	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
1955–59 (average)	4,036	$11,258	218	$403	298	$1,702	4,552	$13,363
1960	3,826	8,736	----------	----------	282	1,570	4,108	10,306
1961	3,359	7,858	----------	----------	262	1,367	3,621	9,225
1962	4,842	10,464	472	883	319	1,508	5,633	12,855
1963	r 3,668	r 8,582	52	226	r 310	r 1,394	4,030	10,202
1964	3,208	7,433	116	382	309	1,413	3,633	9,228

r Revised.

Source: Bureau of the Census.

TABLE 22.—U.S. imports for consumption of hydraulic cement in 1964, by countries and customs districts

(376-pound barrels)

Custom districts	Bahamas	Belgium—Luxembourg	Canada	Colombia	Denmark	France	Germany, West	Japan	Mexico	Netherlands	Norway	Sweden	United Kingdom	Venezuela	Yugoslavia	Total
Alaska	---	---	77,282	---	---	---	---	591	---	---	---	---	227	---	---	78,100
Buffalo	---	---	2,293	---	---	---	137	---	---	---	---	---	---	---	---	2,430
Connecticut	---	---	---	---	---	---	---	---	---	---	949,792	---	---	---	---	949,792
Dakota	---	---	126,699	---	---	---	---	---	---	---	---	---	---	---	---	126,699
Florida	111,637	176,207	---	30,621	---	---	---	16,333	---	---	---	8,936	---	---	---	343,734
Galveston	---	---	---	---	---	---	---	---	---	---	---	---	640	---	---	640
Georgia	---	2,997	---	6,897	---	---	---	---	---	---	---	22,668	5,500	---	---	38,062
Hawaii	---	---	---	---	98	---	---	476	---	---	---	---	---	---	---	574
Laredo	---	---	---	---	---	---	---	---	21,045	---	---	---	---	---	---	21,045
Los Angeles	---	---	---	---	---	---	---	8,648	---	---	---	---	1,911	---	---	10,559
Maine and New Hampshire	---	---	11,742	---	---	---	---	---	---	---	---	---	---	---	---	11,742
Michigan	---	266	108,823	---	---	---	2,785	---	---	---	---	---	---	---	---	111,874
Montana and Idaho	---	---	24,105	---	---	---	---	---	---	---	---	---	---	---	---	24,105
New Orleans	---	8,473	---	---	---	---	---	---	---	252	---	---	---	---	---	8,725
New York	---	1,600	---	---	114,889	12	---	---	---	---	---	---	920	---	---	117,421
North Carolina	---	1,207	---	---	---	---	---	---	---	---	---	---	---	---	---	1,207
Ohio	---	501	24,626	---	---	---	---	---	---	---	---	---	---	---	---	25,127
Oregon	---	---	---	---	---	---	---	24	---	---	---	---	---	---	---	24
Philadelphia	---	---	---	---	---	---	14,207	---	---	---	---	167	133	---	23,206	37,713
Puerto Rico	---	16,624	---	501,253	1,465	11,832	1,121	26,000	---	---	---	---	53	3,625	---	561,973
Rhode Island	---	---	---	52,509	---	---	---	---	---	---	---	19,362	---	---	---	71,871
Rochester	---	---	949,981	---	---	---	---	---	---	---	---	---	---	---	---	949,981
St. Lawrence	---	---	58,987	---	---	---	---	---	---	---	---	---	---	---	---	58,987
San Diego	---	---	---	---	---	---	---	375	101	---	---	---	---	---	---	476
San Francisco	---	---	---	---	---	---	299	351	---	---	---	---	450	---	---	1,100
Vermont	---	---	57,430	---	---	---	---	---	---	---	---	---	---	---	---	57,430
Washington	---	---	18,985	---	---	---	---	2,693	---	---	---	---	---	---	---	21,678
Total:																
Quantity	111,637	207,875	1,460,953	591,280	116,452	11,844	18,549	55,491	21,146	252	949,792	51,133	9,834	3,625	23,206	3,633,069
Value	$267,766	$861,673	$3,693,234	$1,341,768	$458,401	$62,365	$160,077	$228,511	$92,910	$1,286	$1,750,607	$86,364	$70,388	$7,250	$145,451	$9,228,051

Source: Bureau of the Census.

TABLE 23.—U.S. exports of hydraulic cement, by countries

Destination	1962		1963		1964	
	376-pound barrels	Value	376-pound barrels	Value	376-pound barrels	Value
North America:						
Bermuda	3,197	$5,850	1,869	$11,138	27,112	$90,133
Canada	29,867	222,012	110,753	607,512	132,633	818,342
Central America:						
British Honduras	452	3,345	-----	-----	205	1,066
Canal Zone	-----	-----	-----	-----	368	7,296
Costa Rica	16,763	57,080	19,126	37,918	3,894	19,593
El Salvador	124	2,412	57	598	-----	-----
Guatemala	-----	-----	500	2,475	782	4,518
Honduras	-----	-----	394	4,326	20	496
Nicaragua	3,676	17,714	5,798	25,676	2,748	12,735
Panama	-----	-----	42	846	2,164	12,133
Mexico	13,177	95,516	59,786	238,451	62,268	309,358
West Indies:						
British:						
Bahamas	25,122	110,403	132,904	482,965	170,112	678,446
Barbados	25	200	-----	-----	8,040	18,850
Jamaica	-----	-----	1,360	9,130	1,275	5,157
Leeward and Windward Islands	20,832	63,956	28,748	82,374	33,789	85,237
Trinidad and Tobago	798	3,130	252	1,873	1,527	9,638
Dominican Republic	34	210	186	1,020	9,613	24,748
French West Indies	3,687	10,138	-----	-----	9,795	23,338
Haiti	1,000	2,800	3,602	15,556	1,200	3,360
Netherlands Antilles	55	232	885	7,016	66	1,112
Total	118,809	594,998	366,262	1,528,874	467,611	2,125,556
South America:						
Bolivia	2,551	21,392	2,684	25,310	5,250	44,742
Brazil	3,425	73,563	1,913	18,016	-----	-----
Chile	1,604	21,888	5,391	36,485	1,405	14,929
Colombia	380	2,577	275	3,991	1,229	12,120
Peru	2,918	16,540	2,080	11,548	3,633	21,255
Venezuela	-----	-----	292	2,929	569	3,042
Other	439	2,299	458	2,133	282	3,347
Total	11,317	138,259	13,093	100,412	12,368	99,435
Europe:						
Belgium-Luxembourg	596	8,984	30	744	-----	-----
France	-----	-----	-----	-----	1,740	9,084
Germany, West	187	2,300	218	834	509	6,776
Italy	-----	-----	282	2,134	2,530	19,615
Netherlands	1,425	8,042	788	10,787	616	7,819
Switzerland	4,165	12,355	2,263	10,676	-----	-----
Other	273	2,974	1,075	3,974	628	9,807
Total	6,646	34,655	4,656	29,149	6,023	53,101
Asia:						
India	818	4,605	78	917	91	1,807
Indonesia	20,329	98,099	2,610	23,698	75	675
Japan	5,133	49,203	5,112	47,341	7,996	73,643
Korea, South	201,649	846,635	28,347	149,018	148,722	616,151
Kuwait	372	3,548	-----	-----	250	896
Pakistan	128	520	12,613	50,817	31,030	113,709
Philippines	48	900	7,510	44,647	17,963	86,210
Saudi Arabia	166	1,304	109	2,086	249	3,274
Thailand	-----	-----	5,518	25,996	34	228
Turkey	3,543	20,978	1,969	6,668	154	1,577
Other	3,316	14,842	3,171	20,493	4,218	45,977
Total	235,502	1,040,634	67,037	371,681	210,782	944,147
Africa:						
Liberia	2,913	13,501	99	860	9,438	35,102
Libya	3,038	20,135	2,280	11,491	-----	-----
Western Equatorial Africa, n.e.c	-----	-----	4,085	18,203	-----	-----
South Africa, Republic of	974	4,405	168	736	470	3,450
Other	572	1,773	2,363	10,058	4,387	19,779
Total	7,497	39,814	8,995	41,348	14,295	58,331
Oceania	612	4,616	45	653	1,599	9,480
Grand total	380,383	1,852,976	460,088	2,072,117	712,678	3,290,050

Source: Bureau of the Census.

WORLD REVIEW

NORTH AMERICA

Canada.—Cement attained ninth place in value of mineral commodities produced in Canada in 1964. Increased production reflected heavier requirements for cement in general construction work and large dam projects, particularly the Manicougan in Quebec, and the Peace River in British Columbia.

Canada Cement Co., Ltd. completed installation of an additional kiln at Fort Whyte, Manitoba, as did St. Mary's Cement Co., Ltd. at St. Mary's, Ontario. Expansion was underway at the Villeneuve, Quebec, plant of St. Lawrence Cement Co., and the Corner Brook plant of North Star Cement, Ltd. Construction of Nova Scotia's first cement plant was underway at Brookfield by Canada Cement Co., Ltd.

Ocean Cement Ltd. announced it would build a 1 million barrel annual capacity cement plant in 1965 at Prince George, British Columbia. Lake Ontario Cement Ltd. began expanding the capacity of its Picton, Ontario, plant from 2.35 million barrels per year to 4.1 million barrels per year. Inland Cement Co., Ltd. was building a new plant at Tuxedo, Manitoba, and purchased the assets of British American Cement Co., Ltd. halting work on the plant under construction at Rosser near Winnipeg. The Bamberton, British Columbia, operation of Ocean Cement Ltd. was described in detail.[9]

Expansions of the Havelock, New Brunswick plant of Canada Cement Co. Ltd., and the Montreal plant of Miron Co., Ltd., were planned for 1965. A new plant was scheduled for Joliette, Quebec, by Independent Cement, Inc.[10]

Costa Rica.—A consumption tax on cement has been set at $0.26 per 42.5 kilogram bag (approximately equal to a U.S. 94-pound bag) or $3.64 per short ton in bulk.

Jamaica.—Capacity was doubled at the Rockfort plant of the Caribbean Cement Co., Ltd. Kaiser Bauxite Co., began a program of shipping 250,000 long tons of cement-grade bauxite annually to Bahama Cement Co., Freeport, Bahamas.

Mexico.—Cementos Sinaloa, S.A. planned to build a 700,000 barrel per year plant in Hornillos, northern Sinaloa, to produce both standard portland types and portland-pozzolan cement. Employment will total about 150 persons when the $5 million project is completed. Cementos Hidalgo S.C.L., Hidalgo, will expand capacity to about 1.3 million barrels per year by installing a new kiln and other equipment.

Puerto Rico.—Puerto Rican Cement Co., Inc., announced plans to expand production capacity from 8 million barrels per year to 10.5 million barrels by the end of 1966.

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[9] Cummings, J. M. Manufacture of Portland Cement. Western Miner (Vancouver, Canada), v. 37, No. 5, May 1964, pp. 26–29.

[10] Bureau of Mines. Mineral Trade Notes, v. 60, No. 5, May 1965, pp. 9–10.

TABLE 24.—World production of hydraulic cement by countries [1]

(Thousand barrels)

Country	1955–59 (average)	1960	1961	1962	1963	1964 [p]
North America:						
Canada (sold or used by producers)	29,698	30,782	33,010	36,587	37,314	42,075
Costa Rica	---	---	---	---	---	193
Cuba	3,541	[e] 2,345	[e] 2,345	2,345	[e] 2,052	[e] 2,052
Dominican Republic	1,431	997	1,390	1,507	1,343	[2] 1,343
El Salvador	446	504	440	381	457	516
Guatemala	580	657	733	680	921	1,091
Haiti	205	281	258	299	270	328
Honduras	---	217	246	322	352	428
Jamaica	891	1,243	1,266	1,173	1,179	1,648
Mexico	14,260	18,112	17,795	19,654	21,577	25,441
Nicaragua	223	188	229	270	317	358
Panama	451	639	668	715	833	733
Trinidad	850	1,038	575	967	950	1,032
United States (including Puerto Rico)	328,845	334,130	338,628	351,932	368,406	385,387
Total	381,421	391,133	397,583	416,832	435,971	462,625
South America:						
Argentina	13,058	15,485	17,021	17,285	14,770	16,517
Bolivia	182	223	264	293	364	375
Brazil	20,017	26,232	27,622	29,739	30,395	32,623
Chile	4,532	4,896	5,177	5,992	6,837	7,423
Colombia	7,130	8,590	9,334	10,237	10,759	11,521
Ecuador	903	1,179	1,284	1,255	1,513	1,689
Paraguay	70	82	94	94	106	135
Peru	3,319	3,518	3,483	4,110	4,421	4,855
Uruguay	2,199	2,433	2,281	2,193	1,994	2,416
Venezuela	9,346	8,719	8,871	9,000	9,205	10,947
Total	60,756	71,357	75,431	80,198	80,364	88,501
Europe:						
Albania	387	428	704	698	756	[e] 821
Austria	12,307	16,593	18,082	17,924	19,419	22,099
Belgium	26,449	25,728	27,874	28,073	27,610	34,277
Bulgaria	5,769	9,299	10,255	11,099	12,929	15,162
Czechoslovakia	21,718	29,616	31,328	33,479	30,360	32,207
Denmark	7,118	8,455	9,287	9,569	8,918	11,727
Finland	5,910	7,370	7,910	7,956	8,320	9,141
France	72,805	83,101	90,183	98,984	104,367	124,947
Germany:						
East	20,481	29,504	30,958	31,873	32,014	33,843
West	116,885	146,025	159,153	167,649	171,308	145,345
Greece	7,523	9,622	10,771	11,275	13,450	15,667
Hungary	6,913	9,211	9,387	10,161	10,542	13,233
Iceland	[3] 328	428	440	569	575	633
Ireland	3,588	4,368	4,362	4,456	4,702	5,705
Italy	71,737	93,895	105,721	118,274	129,509	133,918
Luxembourg	1,055	1,231	1,354	1,349	1,190	[2] 1,190
Netherlands	7,792	10,542	11,158	11,815	12,202	16,845
Norway	5,717	6,749	7,470	8,279	8,261	8,889
Poland	26,643	38,651	43,177	44,233	44,972	51,368
Portugal	567	7,024	7,294	8,214	8,402	9,510
Rumania	13,849	17,907	19,396	20,457	25,617	27,862
Spain (includes Canary Islands)	29,404	33,614	38,862	42,767	45,429	48,196
Sweden	15,039	16,452	17,660	17,907	19,056	20,914
Switzerland	13,925	17,801	21,114	21,847	20,996	25,341
U.S.S.R. [e]	173,941	266,897	298,231	333,161	357,767	380,528
United Kingdom	73,274	79,137	84,291	83,587	82,086	99,488
Yugoslavia	10,906	14,060	13,697	14,764	16,570	17,819
Total	752,030	983,708	1,080,119	1,160,419	1,217,327	1,306,675

See footnotes at end of table.

TABLE 24.—World production of hydraulic cement by countries [1]—Continued

(Thousand barrels)

Country	1955–59 (average)	1960	1961	1962	1963	1964 [p]
Asia:						
Afghanistan [4]	[5] 199	217	240	352	604	[e] 733
Burma	246	264	235	311	727	768
Ceylon	451	498	481	498	440	440
China	46,144	79,155	46,906	46,906	58,633	[e] 61,565
Cyprus	[6] 317	516	557	575	563	469
Hong Kong	745	879	1,079	1,243	1,272	1,261
India	33,280	45,998	48,343	50,348	54,851	56,815
Indonesia	1,395	2,269	2,609	2,996	1,935	[2] 1,935
Iran [4]	1,947	4,673	4,368	[e] 4,368	[e] 4,368	[e] 4,368
Iraq	3,213	3,624	5,494	5,400	5,283	6,303
Israel	4,093	4,726	4,960	5,594	5,992	6,039
Japan	89,140	132,147	144,448	168,787	175,594	193,196
Jordan	580	967	1,308	1,378	1,671	1,806
Korea:						
North	5,863	13,398	13,263	13,931	14,834	15,303
South	997	2,527	3,067	4,632	4,562	7,282
Lebanon	3,225	5,007	5,125	5,048	5,254	5,259
Malaysia	739	1,677	1,941	1,911	2,123	2,445
Pakistan	5,470	6,796	7,288	8,179	8,783	9,106
Philippines	3,184	4,661	5,975	5,635	5,576	6,226
Saudi Arabia	[5] 440	[e] 528	616	891	1,091	1,407
Singapore	----------	----------	----------	715	1,137	[2] 1,137
Syrian Arab Republic	2,040	2,867	3,166	3,559	4,016	[2] 4,016
Taiwan	4,532	6,936	8,848	10,970	13,169	13,808
Thailand	2,521	3,084	4,673	5,646	5,840	6,115
Turkey	7,394	11,949	11,891	13,620	15,819	17,355
Viet-Nam:						
North [e]	1,343	2,392	2,685	2,709	2,932	3,805
South	----------	----------	----------	----------	----------	440
Total	219,498	337,755	329,566	366,202	397,069	429,402
Africa:						
Algeria	4,497	6,227	6,285	5,130	5,183	4,280
Angola	709	944	921	991	1,137	1,255
Cameroon, Republic of	59	----------	----------	----------	----------	----------
Cape Verde Islands	[7] 18	23	41	[e] 41	[e] 41	[e] 41
Congo, Republic of the (Leopoldville)	2,422	1,173	821	1,155	1,442	[e] 1,583
Ethiopia	164	164	176	240	199	[e] 258
Kenya	1,237	2,070	1,935	2,029	1,994	1,970
Malawi	[5] 205	[e] 176	217	193	147	182
Morocco	3,260	3,401	3,694	4,093	4,450	4,855
Mozambique	997	1,302	1,243	1,050	979	1,067
Nigeria	[5] 721	985	2,134	2,832	3,090	3,870
Rhodesia (formerly Southern)	2,814	[e] 2,597	1,636	[e] 1,466	[e] 1,466	[e] 1,466
Senegal	879	985	1,067	1,073	1,114	1,202
South Africa, Republic of	14,905	15,860	15,233	15,591	16,910	20,264
Sudan	446	709	487	498	[e] 586	586
Tunisia	2,263	2,375	1,929	2,128	2,117	2,668
Uganda	451	422	369	328	322	[2] 322
United Arab Republic (Egypt)	8,777	12,002	12,073	13,562	14,817	13,978
Zambia	850	[e] 745	715	[e] 704	[e] 704	997
Total	45,674	52,160	50,976	53,104	56,698	60,844
Oceania:						
Australia	13,509	16,364	16,757	17,197	18,288	21,260
Fiji Islands	----------	----------	----------	----------	----------	182
New Zealand	2,961	3,618	3,817	3,700	4,233	4,620
Total	16,470	19,982	20,574	20,897	22,521	26,062
World total [e] [1]	1,475,849	1,856,095	1,954,249	2,097,652	2,209,950	2,374,109

[e] Estimate. [p] Preliminary.

[1] This table incorporates some revisions.

[2] 1963 data.

[3] Average annual production 1958–59.

[4] Year ended March 20 of year following that stated.

[5] Data for year 1959 only.

[6] Average annual production 1956–59.

[7] Average annual production 1957–59.

SOUTH AMERICA

Chile.—The capacity of the La Calera plant of Empresas Industriales El Melon, S.A., was increased to 5.7 million barrels per year.

Ecuador.—The operations of La Cemento Nacional, C.A. were summarized.[11] Annual production capacity was 1.5 million barrels. The most recent expansion of the facility included a new kiln and a 50,000 volt electrostatic precipitator to eliminate a dust problem. The firm employed 200 production workers and an office staff of 66 persons. The wholesale price of their product at the plant was reported to be approximately $3.89 per barrel.

EUROPE

Greece.—Plans were announced for a 500,000 ton annual capacity cement plant near Patras. The operation will be a joint venture of the Titan Cement Co., of Greece and the American Cement Corp.[12]

Ireland.—Cement Ltd., Ireland's cement monopoly, expanded capacity to more than 1 million tons a year. By late 1965, capacity will be approximately 1.25 million tons.[13]

Italy.—Per capita consumption of cement increased to approximately 990 pounds in 1964 compared with 960 pounds in 1963. The new 6 million barrel mill of Cementerie Del Tirreno, S.p.A. at Taranto was reported to have a productivity of 3,000 tons of cement per worker per year compared to a national industry average of 1,225 tons.

Poland.—The Warta cement plant at Dizialoszyn began full production in 1964, another plant at Rudniki with a 1.3 million ton capacity began trial runs. The first production of white cement in Poland was started at the Wejherowo cement works.[14]

Sweden.—Sweden's largest cement plant began operating at Gullhogens Bruk, Skovde. The plant, with a 5 million barrel capacity, will be run by only 40 men. It features a 442-foot long rotary kiln and a 295-foot tall stack.

Rumania.—The new cement plant at Birsesti near Tirgu-Jiu will be the nation's largest with an annual capacity of more than 10 million barrels.

U.S.S.R.—The cement mills at Balakleisk and Novorossusk were discussed.[15] At Balakleisk it was reported that capital investment per ton of installed annual capacity was $20.16, annual output per worker was 2,520 metric tons, and cost per ton of cement produced was $6.16. Current Soviet chemical research on cement was summarized.[16] Of particular interest were the discussions of how chemical waste products can be used to extend the raw material base of the cement industry and additives used to increase grinding efficiencies.

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[11] Bureau of Mines. Mineral Trade Notes. V. 58, No. 4, April 1964, p. 8.

[12] Bureau of Mines. Mineral Trade Notes. V. 59, No. 5, November 1964, p. 10.

[13] Bureau of Mines. Mineral Trade Notes. V. 59, No. 3, September 1964, p. 6.

[14] Cement, Lime and Gravel (London). Cement Plant Commissioned In Poland. V. 39, No. 6, June 1964, p. 216.

[15] Cement, Lime and Gravel (London). First Production Lime in Operation at New Russian Cement Mill. V. 39, No. 4, April 1964, pp. 137–138.

————. Three Million Tons a Year of Novorossusk Cement. V. 39, No. 6, June 1964, p. 209.

[16] Cement, Lime and Gravel (London). Soviet Chemical Industry to Help Cement Producers Increase Output and Efficiency. V. 39, No. 7, July 1964, pp. 246–247.

United Kingdom.—Construction was started on a new cement plant at Weardale, County Durham. The Hope Works of G. and T. Earle Ltd., were described.[17] The plant, first erected in 1929, has been constantly modernized to keep abreast of technological developments and has a burning capacity of 67 tons of clinker an hour in 5 rotary kilns.

ASIA

Afghanistan.—The daily production capacity of the Afghanistan cement industry was increased to 500 tons by doubling the capacity of the Ghori plant near Pul-i-Khumri.

Cambodia.—China erected a 50,000 ton capacity cement mill for the Cambodian Government at Chakry Ting in Kampot Province.

Ceylon.—A cement plant was under construction near Puttalam with an annual capacity of 200,000 tons. The plant at Kankesanturai was being expanded from 85,000 tons to 240,000 tons.

India.—Indian cement production capacity was 10.5 million metric tons per year with several additional plants under construction or planned. The Government has entered the cement industry by announcing plans for a public sector plant in Bhilai with a 500,000 ton annual capacity. It will utilize slag from the Bhilai steel plant.[18]

Israel.—The Israeli cement industry was comprised of the Ramle and Haifa plants of Nesher Cement Co., and the Hartuv plant of Shimshoni Portland Cement Co. In 1964 capacity of the Ramle plant was expanded to 3.2 million barrels of cement per year.

Japan.—The Japanese cement industry had a capacity of approximately 50 million tons per year, but domestic consumption was only about 34 million tons. Computer kiln control systems at the Tokuyama plant in Hanshu were described.[19]

Korea, South.—Three new cement plants were opened in 1964, increasing national annual capacity from 800,000 tons to 1.8 million tons. The new plants are the Ssangyong "Twin Dragon" Cement Co., near Yongwol, Kangwon Province; Hanil Cement Co., near Tanyang, Chunchong-Pukdo Province; and Tanyang Cement Co., also near Tanyang.

The new facilities were expected to create a 300,000 to 500,000 ton surplus of cement for export. Korea's five cement manufacturers operate a marketing cartel, Korea Cement Sales Co., "to insure an appropriate level of business profits." [20]

Malaysia.—Two new cement plants were constructed, Tasek Cement Ltd., at Tasek and Pan-Malaysia Cement Works, Ltd., at Kanthan. Pan-Malaysia initial production rate was 500 tons per day.

Okinawa.—A 900,000 barrel plant was built near Nago by Ryukyu Cement Co., Ltd.; commercial operation began late in 1964. Kaiser Cement & Gypsum Corp. acquired a 30 percent interest in the firm.

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[17] Cement, Lime and Gravel (London). Cement-Making In Derbyshire. V. 39, No. 4, April 1964, pp. 118–124.

[18] Journal of Mines, Metals and Fuels (Calcutta, India). Cement Factory in Bhilai. V. 12, No. 1 January 1964, p. 28.

[19] Kaiser, V. A., and Y. Schioya. Computer Controls Two Kilns at Japanese Cement Plant. Rock Products, Min. and Processing, v. 67, No. 2, February 1964, pp. 88, 90, 92, 95.

[20] Bureau of Mines. Mineral Trade Notes. V. 60, No. 2, February 1965, p. 9.

Pakistan.—A 1,200 ton per day cement plant was erected by Ismail Cement Industries, Ltd., at Gharibwal, West Pakistan. Plans were announced for a white cement plant at Dandkhel and for two new kilns at the Zeal Pak plant at Hyderabad.[21]

Philippines.—Marinduque Mining and Industrial Corp. signed a contract with Kobe Steel Works Ltd., for installation of a 1,300 ton per day wet process plant.[22]

Turkey.—The Turkish Cement Corp., announced plans for a 300,000 ton, $7.1 million plant at Trabizon.

AFRICA

Kenya.—The British Standard Portland Cement Co., Ltd., announced plans to improve its Bamburi plant which would bring total annual capacity to 600,000 tons.

Nigeria.—Construction of a 100,000 ton per year cement plant was begun at Kalainbaina near Sokoto. Completion is scheduled for 1965.

South Africa, Republic of.—Anglo-Alpha Cement Ltd., planned to build a 475,000 short ton per year cement plant near Lichtenburg in the northwestern Transvaal. It will increase South African cement capacity more than 10 percent when compared with present capacity of 4 million tons in 13 plants.

Tunisia.—The two cement plants in Tunisia were Société des Ciments Portland de Bizerte at Bizerte, and Les Ciments Artificiels Tunisiens, near Tunis. Respective annual capacities were 175,000 and 320,000 tons.[23]

United Arab Republic (Egypt).—Production capacity was to be increased at Tura, Helwan, and Alexandria. New plants will be erected at Suez and Assiout. By 1970 it was planned to produce 4 million tons of cement per year, of which 1 million tons will be available for export.[24]

OCEANIA

Australia.—Southern Portland Cement Co., Ltd., Berrima, doubled its capacity to 770,000 tons per year. By the end of 1964, Australian cement production capacity was estimated to be about 4.4 million tons. Australian Portland Cement, Ltd., was expanding its plant at Geelong.

New Zealand.—Wilson Portland Cement, Ltd., announced it will expand clinker production capacity at Whangarei from 200,000 to 500,000 tons per year. The motor vessel *Ligar Bay* entered service as a cement carrier with Golden Bay Cement Co., Ltd. The ship, with a capacity of 1,200 tons of cement, will carry cement from the plant at Tarakohe, South Island to distribution terminals on both South and North Islands.

TECHNOLOGY

Automation and computer control of cement plants continued to be a major item of technological interest. Numerous articles discussed instrumentation, efficiency, maintenance, operation, process savings, and other factors.[25]

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[21] Bureau of Mines. Mineral Trade Notes, v. 59, No. 1, July 1964, p. 6; v. 59, No. 5, November 1964, p. 11.

[22] Bureau of Mines. Mineral Trade Notes. V. 58, No. 6, June 1964, p. 8.

[23] Bureau of Mines. Mineral Trade Notes. V. 59, No. 5, November 1964, p. 11

[24] Bureau of Mines. Mineral Trade Notes. V. 59, No. 4, October 1964, p. 9.

The Riverside (California) Division of American Cement Corp. began construction of a $1.6 million laboratory for the study of new methods of using and new uses for cement. Research on the use of cement in combination with other materials such as epoxy glues also will be undertaken.

Considerable interest was generated during the year by severe cracking and spalling of concrete in the 2-year old Washington, D.C., Stadium. Investigation revealed the cause of failure to be electrolytic action resulting from embedded aluminum conduits in combination with calcium chloride added to the portland cement concrete to hasten setting in cold weather. As a result, an increasing number of building departments are banning the use of aluminum conduit in concrete.

The equipment and techniques employed for measuring the mechanical properties of cement, mortar and concrete were described.[26] The National Bureau of Standards reported on their studies involving the hydration of iron compounds during the setting of cement.[27] Knowledge of these chemical reactions is essential for proper cement formulation and to prevent deterioration of cement in use.

A comprehensive textbook on cement chemistry was published.[28] This 2-volume set was of special interest because it included several highly informative chapters on mineral cements other than portland types.

Raw Materials and Beneficiation.—Unusual cement raw materials, such as anorthosite and spent oil shale, were the objects of interest during the year.[29]

The beneficiation of limestone to cement raw material quality was discussed.[30] Such measures serve the multiple purpose of enabling better utilization of available stone, facilitating quarry planning, and enabling improved quality control.

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[25] Andrews, J. C. Instrumentation in Minerals Processing. Min. Cong. J., v. 50, No. 7, July 1964, pp. 24–29.

Campbell, R. E. Computer-Burner-Kiln. Miner. Processing, v. 5, No. 4, April 1964, pp. 42–44.

Carlson, P. E. Modern Production on a 44-year Old Site. Miner. Processing, v. 5, No. 11, November 1964, pp. 22–25.

Gieskieng, D. H. A Cement Clinker Quality Signal. Miner. Processing, v. 5, No. 5, May 1964, pp. 28–31.

Peirce, J. W. Basing Cement Plant Instrumentation on Predictable Savings. Pit and Quarry, v. 56, No. 10, April 1964, pp. 139–140, and 153.

Striker, R. H. Application of Process Instruments-Cement Industry. Miner. Processing, v. 5, No. 6, June 1964, pp. 20–25.

Walkling, Walter and J. H. Jacoby, Finger Tip Control. Miner. Processing, v. 5, No. 4, April 1964, pp. 32–36.

Weeks, L. W. Control of Kiln Operations With A Digital Computer. Min. Cong. J., v. 50, No. 6, June 1964, pp. 42–45.

Willis, V. Cement Kiln Regulations by Digital Process Control Computer. Cement, Lime, and Gravel (London), v. 39, No. 8, August 1964, pp. 261–265.

[26] Pilpel, N. The Rheological Properties of Cement and Concrete. Cement, Lime, and Gravel (London), v. 39, No. 3, March 1964, pp. 79–84.

[27] Carlson, E. T. Hydration of Iron Compounds in Cement. Technical News Bulletin of the National Bureau of Standards, v. 48, No. 11, November 1964, pp. 200–201.

[28] Taylor, H. F. W. (ed.). The Chemistry of Cements. The Academic Press, Inc., New York, 1964, 442 p.

[29] Culbertson, W. J., Jr. (assigned to the Oil Shale Corp., Beverly Hills, Calif.). Method for Making Cement. U.S. Pat. 3,127,455, Mar. 31, 1964.

Diehl, K. B., Cement and Alumina from Anorthosite. Miner. Processing, v. 5, No. 8, August 1964, pp. 14–16.

Friese, Gunter (assigned to Metallgesellschaft, A. G., Frankfurt-am-Main, West Germany). Process for Producing Cement Using Pretreated Oil Shale. U.S. Pat. 3,135,618, June 2, 1964.

[30] Klieber, J. C., and G. M. Meisel. Floating Limestone at Permanente. Min. Eng., v. 16, No. 3, March 1964, pp. 39–44.

Slotemaker, J. R. New Photocell Sorting Device Piloted at Limestone Quarry. Min. Eng., v. 16, No. 1, January 1964, pp. 41–43.

X-ray spectrographic techniques as an aid to prospecting for cement raw materials were described.[31]

Kiln Feed and Slurries.—Patents were issued for manufacture of cement from raw materials containing free lime in the kiln feed mixture.[32]

Preheating.—Methods and apparatus for preheating cement raw materials were patented.[33] The use of preheating devices increases the thermal efficiency and lowers fuel costs for the cement manufacturing process.

Calcination and Kilns.—Patents were issued on kiln designs featuring improved heat transfer chains and internal plowing elements intendes to enchance the thermal efficiency of kilns.[34] A new calcining apparatud featured molten flow of the materials being burned down an inclined plane.[35] The increasing size and weight of rotary kilns has resulted in need for greater reliability and rigorous speed control in kiln drive. Static drives, the most popular means of achieving the desired performance, were reviewed.[36]

Cooling.—Relative heat recuperation, cooling efficiency, and design of rotary coolers was discussed.[37] Methods of redesigning low-recuperative installations, to high thermal recuperating efficiency and concomitant plant fuel savings were included in the paper.

Grinding.—Production of uniform-colored cement has been an industry problem. A suggested solution is to wet-grind clinker with pigment in an inert nonaqueous liquid, and then to evaporate the liquid. The liquid can be recondensed for recycling.[38]

Special Cements and Additives.—Polyester resin as a cement additive was of continued interest,[39] for its strength, adhesion characteristics, and resistance to chemical attack. Calcium aluminate and aluminosulfate cements received considerable attention and were the subject of further research.[40]

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[31] Robinson, J. M. M., and E. P. Gertiser, X-Ray Spectrographic Analysis of Raw Materials for the Cement Industry. Materials Research and Standards, v. 4, No. 5, May 1964. pp. 228–231.

[32] Smothers, W. J. (assigned to the Ohio Brass Co., Mansfield, Ohio). Preparation of Cement Composition. U.S. Pat. 3,147,126, Sept. 1, 1964.

Wuhrer, Josef (assigned to Rheinische Kalksteinwerke, G.m.b.H., Wulfrath, West Germany). Process for the Manufacture of Cement. U.S. Pat. 3,139,463, June 30, 1964.

[33] Forsyth, G. H., and Others (assigned to Vickers-Armstrong Ltd., London, England). Apparatus for Heating Powdered Materials Such as Raw Cement. U.S. Pat. 3,140,863, July 14, 1964.

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The advantages of adding phosphogypsum to the cement raw materials batch were discussed.[41] Superior clinker properties and more resistant kiln linings were claimed.

Special Concretes.—The chemistry of concrete was lucidly set forth in an attractively illustrated article for a general audience.[42] Improved methods for proportioning and mixing ready-mixed concrete were discussed.[43] An analysis of concrete hauling costs and effect of mixing plant location was included.

Concrete additives, designed to produce certain changes in plastic or hardened concrete were discussed.[44] The properties of concrete containing special or unusual components were described in several publications.[45] One of these products, expansive concrete, continued to be a cause of considerable engineering interest due to its claimed advantages of eliminating drying shrinkage cracks in concrete.

Dust and Pollution Control.—Improved methods and equipment for decreasing dust problems in the vicinity of cement plants were of continued interest. Louisiana Cement Co. plant at New Orleans East, La., was required to achieve super-critical cleanliness because of its proximity to the National Aeronautics and Space Agency Michoud Operations Base. Means of achieving high efficiency in dust recovery were described.[46] A technique for enabling more efficient recovery of dust from cement kiln waste gases was patented.[47]

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Chromium

By R. W. Holliday[1]

◆

WORLDWIDE DEMAND, and prices, for chromite showed improvement compared with the very low levels of 1963, and production increases were reported by most of the major producing nations because of the high level of steel production. However, traditional suppliers did not benefit fully from the increased demand because of the continued large-scale shipment of high-quality, low-cost chromite from the U.S.S.R.

Imports of chromite from the U.S.S.R. comprised 19 percent of total U.S. imports compared with 14 percent in 1963. Most of this material, from the U.S.S.R., was consumed by the metallurgical industry. Domestic ferrochrome producers had little alternative to acceptance of this low-cost chromite because it was used in quantity by competitors in Western Europe and Japan.

TABLE 1.—Salient chromite statistics

(Thousand short tons and thousand dollars)

	1955-59 (average)	1960	1961	1962	1963	1964
United States:						
Imports for consumption	1,822	1,387	1,329	1,446	1,391	1,428
Exports	3	5	5	3	10	6
Consumption	1,550	1,220	1,200	1,131	1,187	1,450
Stocks Dec. 31: Consumer	1,458	1,707	1,633	1,700	1,583	1,287
World: Production[1]	4,435	4,885	4,650	4,845	4,355	4,720

[1] Incorporates some revisions.

LEGISLATION AND GOVERNMENT PROGRAMS

Refractory grade chromite was eligible for acquisition under the agricultural barter program administered by the U.S. Department of Agriculture, Commodity Credit Corporation, but no transactions were negotiated. Government financial assistance was available for exploring domestic chromite deposits upon approval by the U.S. Department of the Interior, Office of Minerals Exploration.

The General Services Administration requested congressional authorization for the disposal of 33,552 pounds of chromium metal, which did not meet quality requirements and was in excess of stockpile needs.

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The Director of the Office of Emergency Planning ruled that imports of manganese and chromium ferroalloys and metals were not threatening to impair the national security (PR 202, July 17, 1964). The determination, under authority of Section 232 of the Trade Expansion Act, was made in reply to an application of May 20, 1963, by the Manufacturing Chemists Association, Inc., on behalf of domestic ferroalloys manufacturers.

The U.S. Tariff Commission determined that the importation of chromic acid from Australia, sold at less than fair value within the meaning of the Antidumping Act, 1921, as amended, was injurious to the domestic industry.

TABLE 2.—Chromium materials in Government inventories on Dec. 31, 1964

(Thousand short dry tons)

Chromite [1]	National (strategic stockpile)	DPA inventory	CCC and supplemental stockpile	Total	Percent of maximum objective
Chemical grade	559		700	1,259	209.8
Metallurgical grade	3,736	1	1,707	5,444	183.8
Refractory grade	1,047		180	1,227	86.1

[1] Including chromite ore and ore equivalent of upgraded materials.

DOMESTIC PRODUCTION

Domestic chromite mining has been inactive since 1961 but the United States continued as the major importer and processor of chromite ores. Imports of chromite, all types, were equivalent to 30 percent of the estimated world production in 1964. Two firms produced chromium metal and eight firms produced chromium ferroalloys during the year. Chromite-bearing refractories were produced by nine firms and chromium chemicals were produced by five firms.

CONSUMPTION AND USES

Industrial consumption of chromite in 1964 was the highest on record.

The metallurgical industry consumed 817,000 tons of chromite containing 274,000 tons of chromium in producing 349,000 tons of chromium ferroalloys and chromium metal containing 219,000 tons of chromium. An additional 15,000 tons of chromite was added directly to steel. Of the 817,000 tons consumed in making chromium ferroalloys and metal, 682,000 tons (averaging 49.2 percent Cr_2O_3) was classified by consumers metallurgical-grade ore; 78,000 tons (averaging 49.5 percent Cr_2O_3) was classified as chemical-grade ore; and 56,000 tons (averaging 46.8 percent Cr_2O_3), as refractory-grade ore. Seventy-eight percent of the metallurgical grade ore had a Cr : Fe ratio of 3 : 1 and above, 13 percent had a ratio between 2 : 1 and 3 : 1, and 9 percent a ratio of less than 2 : 1.

Producers of chromite-bearing refractories consumed 422,000 short tons of ore containing 97,000 tons of chromium, and an additional 8,000 tons of ore containing 2,400 tons of chromium was used directly in furnace repairs.

The chemical industry consumed 188,000 tons of chromite containing 58,000 tons of chromium in producing 135,000 tons of chemicals (sodium bichromate equivalent).

TABLE 3.—Consumption of chromite and tenor of ore used by primary consumer groups in the United States

(Thousand short tons)

Year	Metallurgical industry		Refractory industry		Chemical industry		Total	
	Gross weight	Average Cr_2O_3 (percent)	Gross weight	Average Cr_2O_3 (percent)	Gross weight	Average Cr_2O_3 (percent)	Gross weight	Average Cr_2O_3 (percent)
1955–59 (average)	992	46.8	406	34.7	152	45.4	1,550	43.4
1960	665	46.4	391	34.9	164	45.3	1,220	42.6
1961	662	46.5	375	34.6	163	45.2	1,200	42.6
1962	590	46.6	365	35.0	176	45.3	1,131	42.7
1963	632	48.7	368	34.6	187	45.1	1,187	43.8
1964	832	49.0	430	33.8	188	45.1	1,450	44.0

TABLE 4.—Production, shipments, and stocks of chromium ferroalloys and chromium metal in 1964

(Short tons)

Alloy	Production		Shipments	Producer stocks Dec. 31
	Gross weight	Chromium content		
Low-carbon ferrochromium	112,091	77,212	126,974	4,265
High-carbon ferrochromium	159,049	107,624	174,629	15,038
Ferrochromium silicon	65,133	26,535	76,159	6,398
Other [1]	12,866	7,844	14,166	1,656
Total	349,139	219,215	391,928	27,357

[1] Includes chromium briquets, chromium metal, exothermic chromium additives, and other miscellaneous chromium alloys.

TABLE 5.—Consumption of chromium ferroalloys and chromium metal in the United States, in 1964 by major end uses

(Short tons)

	Low-carbon ferrochromium	High-carbon ferrochromium	Ferrochromium silicon	Exothermic ferrochromium silicon	Chromium briquets	Other [1]	Total
Stainless steels	125,114	70,432	72,549	7	697	110	268,909
High-speed steels	543	889	49	----------	----------	16	1,497
Other tool steels	983	1,688	70	----------	----------	9	2,750
Other alloy steels [2]	15,161	46,380	8,750	5,628	580	10,042	86,541
Gray and malleable iron	592	4,230	553	----------	368	673	6,416
High-temperature alloys	5,497	637	234	----------	14	1,341	7,723
Nickel-base alloys	360	59	3	----------	----------	59	481
Other nonferrous alloys [3]	550	1,503	1	----------	10	751	2,815
Total	148,800	125,818	82,209	5,635	1,669	13,001	377,132
Chromium content	103,151	82,297	32,240	2,384	925	7,137	229,144

[1] Includes exothermic high- and low-carbon ferrochromium, chromium metal, and other chromium alloys.

[2] Includes quantities that were believed used in producing high-speed and other tool steels and stainless steels because some firms failed to specify individual uses.

[3] Includes cutting and wear resistant alloys, hard-facing alloys, welding rods, electrical-resistance alloys, and other nonferrous alloys.

STOCKS

Chromite stocks shown in table 6 include industry stocks at all locations but do not include Government stockpiles.

Stocks of chromium chemicals at producer plants totaled 6,901 tons (sodium bichromate equivalent) at yearend.

TABLE 6.—Consumers' stock of chromite, Dec. 31

(Thousand short tons)

Industry	1960	1961	1962	1963	1964
Metallurgical	863	[1] 773	[1] 771	686	509
Refractory	719	728	764	723	600
Chemical	125	132	165	174	178
Total	[1] 1,707	[1] 1,633	[1] 1,700	1,583	1,287

[1] Includes stocks at locations other than consumer plants.

TABLE 7.—Consumers' stocks of chromium ferroalloys and chromium metal, Dec. 31

(Short tons)

	1960	1961	1962	1963	1964
Low-carbon ferrochromium	5,125	10,006	5,531	7,293	12,219
High-carbon ferrochromium	5,427	10,086	5,684	6,049	13,862
Ferrochromium silicon	3,061	5,022	2,119	2,558	6,455
Exothermic ferrochromium silicon	771	822	729	610	775
Chromium briquettes	695	513	409	276	328
Other (including chromium metal, exothermic high- and low-carbon ferrochromium, and other chromium alloys	1,451	1,754	1,330	1,477	1,675
Total	16,530	28,203	15,802	18,263	35,314

PRICES

Improvement in demand, due to the high level of activity in the steel industry, did not bring proportionate increases in price. Remaining unsold stocks in some producing countries, new ferrochromium producers in Africa utilizing the Transvaal chemical grade chromite, and continued availability of high-quality chromite from the U.S.S.R. all tended to restrain prices. However, substantial reductions of stocks did occur, and some increase was indicated in the future prices for Soviet chromite. Thus, prices at the end of 1964 appeared to be on a relatively firm basis and probably somewhat higher than at the year's beginning.

E&MJ Metal and Mineral Markets published no quotations for chromite until December 21. The yearend quotations are listed in table 8.

Prices for chromium ferroalloys, at a low level during early months, were increased by most firms during the first week of October. Shortages leading to these increases were thought at first to be temporary, because raw materials and productive capacity were adequate. However, additional price increases were announced effective Jan. 1, 1965. These prices for chromium ferroalloys quoted by E&MJ Metal and Mineral Markets for lump material in bulk carload

TABLE 8.—Price quotations for various grades of foreign chromite in 1964

Source	Cr_2O_3 (percent)	Cr/Fe ratio	Price per long ton[1] Dec. 31
Southern Rhodesia	48	3:1	$32.00–$35.00
Do	48		30.00– 31.00
South Africa, Republic of (Transvaal)	44		18.00– 19.00
Turkey	48	3:1	30.00– 32.00

[1] Quotations are on a dry basis, subject to penalties if guarantees are not met, f.o.b. Atlantic ports.

Source: E&MJ Metal and Mineral Markets.

lots, f.o.b. shipping point, per pound of contained chromium were: High-carbon ferrochromium (67–71 percent chromium, all grades carbon) 19 cents; low-carbon ferrochromium (67–73 percent chromium, 0.025 percent carbon) 24.5 cents; charge chrome (61–66 percent chromium, 5.5 percent carbon) 13.5 cents; and refined chrome (61–68 percent chromium, 4.25 percent carbon) 22 cents.

Electrolytic chromium metal (99.8 percent pure) and aluminothermic chromium metal (98.5 percent chromium, 0.5 percent carbon) were quoted at $1.15 to $1.19 per pound, delivered.

FOREIGN TRADE

Imports.—The quantity of chromite ores and concentrates imported into the United States increased by nearly 3 percent compared with that of 1963, and the reported value increased by nearly 13 percent. The Republic of South Africa (30 percent), Rhodesia (24 percent), the U.S.S.R. (19 percent), and the Philippines (16 percent) supplied 89 percent of total imports.

Imports for consumption of chromium, unwrought, and waste and scrap not alloyed, totaled 732 tons valued at $1,108,941; 415 tons came from Japan, 210 tons from the United Kingdom, 97 tons from France, and 10 tons from West Germany. Sodium chromate and dichromate totaling 3,454 tons valued at $671,428 was imported from Japan (1,835 tons), the Republic of South Africa (1,593 tons), and Mexico (26 tons). Imports of chromium zinc yellow were 166 tons valued at $61,462; chrome yellow, 753 tons valued at $321,864; chrome green, 58 tons valued at $33,923; and chromium oxide green, 242 tons valued at $142,775.

Exports.—Exports of chromium products included 891 tons of chromic acid valued at $522,541; sodium bichromate and chromate, 6,669 tons valued at $1,459,127; chromium and chromium bearing alloys in crude form and scrap, 44 tons valued at $40,124; and chromium and chromium alloys in semifabricated forms, 2 tons valued at $35,924. Reexports of chromite ore and concentrates, mostly to Canada, Mexico, and Venezuela, totaled 32,116 tons valued at $1,256,282.

TABLE 9.—U.S. imports for consumption of chromite, by grades and countries, in 1964

Country	Not more than 40 percent chromic oxide (Cr_2O_3)			More than 40 percent but less than 46 percent chromic oxide (Cr_2O_3)			46 percent or more chromic oxide (Cr_2O_3)			Total		
	Short tons		Value	Short tons		Value	Short tons		Value	Short tons		Value
	Gross weight	Cr_2O_3		Gross weight	Cr_2O_3		Gross weight	Cr_2O_3		Gross weight	Cr_2O_3	
Europe:												
Latvia	-	-	-	-	-	-	22,179	12,381	$413,837	22,179	12,381	$413,837
U.S.S.R.	-	-	-	-	-	-	275,045	150,419	4,963,745	275,045	150,419	4,963,745
Total	-	-	-	-	-	-	297,224	162,800	5,377,582	297,224	162,800	5,377,582
Asia:												
India	-	-	-	-	-	-	3,491	1,866	84,173	3,491	1,866	84,173
Philippines	226,586	71,632	$4,041,500	5,600	2,408	$105,000	-	-	-	232,186	74,040	4,146,500
Turkey	17,517	6,850	175,817	51,203	22,501	1,050,062	37,575	18,017	808,910	106,295	47,368	2,034,789
Total	244,103	78,482	4,217,317	56,803	24,909	1,155,062	41,066	19,883	893,083	341,972	123,274	6,265,462
Africa:												
Mozambique	-	-	-	8,703	3,780	80,138	-	-	-	8,703	3,780	80,138
South Africa, Republic of	17,024	5,618	152,000	350,179	154,465	3,087,727	63,854	29,934	941,965	431,057	190,017	4,181,602
Southern Rhodesia	-	-	-	88,413	39,380	1,616,551	248,790	121,333	4,982,154	337,203	160,713	6,598,705
Sudan	-	-	-	11,612	5,109	209,434	-	-	-	11,612	5,109	209,434
Total	17,024	5,618	152,000	458,907	202,734	4,993,850	312,644	151,267	5,924,119	788,575	359,619	11,069,969
Grand total	261,127	84,100	4,369,317	515,710	227,643	6,148,912	650,934	333,950	12,194,784	1,427,771	645,693	22,713,013

Source: Bureau of the Census.

TABLE 10.—U.S. imports for consumption of ferrochromium, by countries

Year and country	Low-carbon ferrochromium (less than 3 percent carbon)			High-carbon ferrochromium (3 percent or more carbon)		
	Short tons		Value	Short tons		Value
	Gross weight	Chromium content		Gross weight	Chromium content	
1963:						
North America: Canada	----	----	----	2,947	1,625	$514,137
Europe:						
France	4,405	3,163	$1,151,547	28	19	6,597
Germany, West	803	591	253,640	110	77	21,912
Italy	----	----	----	21	14	4,177
Norway	5,076	3,503	1,219,177	598	422	113,053
Sweden	8,164	5,979	2,105,402	359	247	66,612
Yugoslavia	502	356	154,956	----	----	----
Total	18,950	13,592	4,884,722	1,116	779	212,351
Asia: Japan	3,151	2,112	775,623	939	628	132,366
Africa:						
South Africa, Republic of	102	57	24,951	[r] 1,530	[r] 929	[r] 184,421
Southern Rhodesia	308	223	78,353	----	----	----
Total	410	280	103,304	1,530	929	184,421
Grand total	22,511	15,984	5,763,649	6,532	3,961	1,043,275
1964:						
Europe:						
France	260	202	72,311	----	----	----
Germany, West	432	314	131,102	----	----	----
Norway	10,453	7,334	2,534,659	219	155	41,580
Sweden	4,965	3,587	1,228,013	----	----	----
Switzerland	28	21	8,093	----	----	----
United Kingdom	(1)	(1)	260	----	----	----
Total	16,138	11,458	3,974,438	219	155	41,580
Asia: Japan	1,450	959	329,835	384	259	58,485
Africa:						
South Africa, Republic of	517	288	93,102	6,867	4,141	1,157,035
Southern Rhodesia	547	436	128,622	----	----	----
Total	1,064	724	221,724	6,867	4,141	1,157,035
Grand total	18,652	13,141	4,525,997	7,470	4,555	1,257,100

[r] Revised figure, includes 1,129 short tons, gross weight, and 692 short tons, chromium content, valued at $129,870, formerly reported as Mozambique.

(1) Less than ½ unit.

Source: Bureau of the Census.

TABLE 11.—U.S. exports of chromite ore and concentrate

Year	Exports		Reexports	
	Short tons	Value	Short tons	Value
1955–59 (average)	3,140	$161,389	19,941	$801,010
1960	5,184	320,179	19,927	720,575
1961	5,201	344,907	35,890	1,373,083
1962	2,686	108,112	51,254	2,032,941
1963	9,726	352,181	[r] 63,764	2,505,000
1964	6,366	240,512	32,116	1,256,282

[r] Revised.

Source: Bureau of the Census.

WORLD REVIEW

United States consumption of chromite increased 22 percent. World steel production increased about 12 percent from the 1963 level, and, presumably, world consumption of chromite also increased at about the same rate. Although gains by the free world chromite mining industry were not this high, reduction in stocks, increased production, and increased exports were reported from most producing areas.

TABLE 12.—World production of chromite by countries [1] [2]

(Short tons)

Country [1]	1955–59 (average)	1960	1961	1962	1963	1964 [p]
North America:						
Cuba	79,602	[3] 32,774	[e] 27,600	[e] 38,600	[e]55,800	[e] [4] 55,800
Guatemala	798	200	110	22	--------	--------
United States	[5] [6] 155,173	[6] 107,000	[6] 82,000	--------	--------	--------
Total	235,573	139,974	109,710	[e] 38,600	[e] 55,800	[e] [4] 55,800
South America:						
Brazil	6,105	6,246	17,037	27,380	48,546	[4] 48,546
Colombia	[7] 55	77	204	154	121	441
Total	6,160	6,323	17,241	27,534	48,667	48,987
Europe:						
Albania	191,921	318,650	256,241	277,007	322,977	[e] 342,000
Greece (marketable)	39,088	38,451	34,324	26,633	18,347	[4] 18,347
U.S.S.R. [e] [8]	850,000	1,010,000	1,015,000	1,270,000	1,355,000	1,435,000
Yugoslavia	129,151	110,873	119,188	106,974	103,364	97,398
Total [1] [e]	1,230,000	1,510,000	1,450,000	1,710,000	1,830,000	1,920,000
Asia:						
Cyprus	[9] 9,607	[9] 15,702	[9] 21,078	[9] 10,669	[9] 448	3,341
India	84,585	110,354	50,625	73,467	71,419	36,844
Iran [10]	43,283	74,957	81,268	121,254	[e] 110,000	[e] 128,000
Japan	46,833	74,394	77,373	64,024	48,205	48,467
Pakistan	23,993	20,265	28,116	23,671	16,023	14,893
Philippines	683,292	809,579	705,811	585,643	506,094	515,969
Turkey	749,051	530,676	443,932	580,964	312,817	454,907
Viet-Nam, North [e]	[7] 7,300	21,400	32,500	35,900	33,400	33,100
Total [8]	1,647,944	1,657,327	1,440,703	1,495,592	1,098,406	1,235,521
Africa:						
Malagasy Republic	--------	--------	11,600	20,342	12,346	12,974
Sierra Leone	19,736	6,023	--------	12,621	3,067	--------
South Africa, Republic of	693,551	850,921	989,725	1,006,173	873,212	936,468
Southern Rhodesia	542,837	668,401	590,888	507,685	412,392	493,368
Sudan	--------	--------	--------	8,800	[e] 18,700	18,700
United Arab Republic (Egypt)	320	331	1,532	--------	--------	--------
Total	1,256,444	1,525,676	1,593,745	1,555,621	1,319,717	1,461,510
Oceania:						
Australia	2,249	592	--------	413	180	[4] 180
New Caledonia	55,241	43,166	40,413	17,036	--------	--------
Total	57,490	43,758	40,413	17,449	180	[4] 180
World total (estimate) [1]	4,435,000	4,885,000	4,650,000	4,845,000	4,355,000	4,720,000

[e] Estimate. [p] Preliminary.

[1] In addition to countries listed, Bulgaria and Rumania produce chromite, but data on output are not available; estimates by author of chapter included in total.

[2] This table incorporates some revisions. Data do not add exactly to totals shown because of rounding where estimated figures are included in the detail.

[3] United States imports.

[4] 1963 data.

[5] Includes 41,467 tons of concentrates produced in 1956 from low-grade ores and concentrates stockpiled near Coquille, Oregon, during World War II.

[6] Produced in 1959, 1960, and 1961 for Federal Government only; excludes quantity consumed by American Chrome Company.

[7] One year only as 1959 was the first year of commercial production.

[8] Output from U.S.S.R. in Asia included with U.S.S.R. in Europe.

[9] Exports.

[10] Year ended March 20 of year following that stated.

EUROPE

U.S.S.R.—Exports to the United States increased from 191,706 short tons in 1963 to 297,224 tons averaging 54.8 percent Cr_2O_3. Exports to Japan were believed to be on the order of 82,000 tons and to Western Europe at least 220,000 short tons which was reported as the 1963 shipment. These comprised an estimated total of some 600,000 tons that may have been augmented by a limited export of chromium in the form of ferrochromium.

ASIA

India.—Negotiations were in progress for establishment of facilities to produce ferrochromium in India. The government owned Metals and Minerals Trading Corp. and Showa Denko K.K. of Japan, discussed plans to produce 15,000 tons of ferrochromium per year in India.

Iran.—Chromite shipments to Western Europe and Japan increased during 1964. Low-cost mining, good-quality ore, a substantial increase in reserves, and a harbor development project under construction at Bandar Abbas, indicated the growing importance of Iran in the world chromite market. The harbor development was being financed by a $15 million loan arranged through the U.S. Agency for International Development.

Japan.—The limited domestic production was used primarily in refractories. Major sources of chromite were the U.S.S.R. and the Philippines.

An announcement was made in December that Japanese ferroalloy producers had contracted for use in 1965 of 25,000 tons of chromite ore from the Faryab Mining Co. of Iran which is affiliated with Philipp Brothers (Division of Minerals and Chemicals Philipp Corp.). Also in December, an announcement was made that 3,500 tons of low-carbon ferrochrome had been sold to Philipp Bros. for delivery in 1965.

Pakistan.—A barter agreement with Poland, early in the year, reduced stocks of chromite below 15,000 tons, suggesting that further sales would necessitate resumption of chromite production.

Turkey.—Chromite exports in 1964 increased 65 percent in tonnage and 55 percent in value compared with those of 1963. Of the total export tonnage, 23.7 percent was shipped to the United States, 17.8 percent to France, 17.6 percent to Czechoslovakia, 9.1 percent to Austria, 9.0 percent to Italy, 6.8 percent to Yugoslavia, 4.5 percent to West Germany, 3.3 percent to the United Kingdom, and the remaining 8 percent to 8 other countries.

Encouraged by strong demand at the yearend, some of the small producers reportedly were preparing to resume operations.

AFRICA

A new ore handling installation at Lourenco Marques, Mozambique, designed to handle iron ore from Swaziland and chromite ores from Rhodesia and the Republic of South Africa, began operation in December. It consists of railroad car tippling units, bucket wheel stackers, reclaimer, and belt conveyors, with weighing and sampling stages between the storage areas and shiploading towers.

South Africa, Republic of.—Production increased 7 percent to 936,468 short tons. Local sales totaled 133,765 tons valued at $976,823, and exports totaled 705,618 tons valued at $6,635,630.

Two new ferrochromium plants, designed to use Transvaal chemical grade ore, began production in May. One was Transalloys (Pty.) Ltd., the Anglo American-Avesta of Sweden subsidiary at Witbank, built at a cost of $8.4 million, with initial annual capacity of 15,000 tons of low-carbon ferrochromium, 5,000 tons of high-carbon ferrochromium, and 1,000 tons of ferrochromium silicon. The other plant, at Middleburg in the Transvaal, was built for R.M.B. Alloys (Pty.) Ltd., a Rand Mines subsidiary; it cost $7.0 million, and will produce at an annual rate of 35,000 tons of low-carbon ferrochromium.

Southern Rhodesia.—Chromite production increased nearly 20 percent compared with output in 1963, and at yearend at least one firm, Rhodesia Chrome Mines Ltd., at Selukwe, reported capacity operations, with output limited only by the availability of railway cars.

TECHNOLOGY

A methods and costs report described 7 years of operation at the Mouat Mine, Nye, Mont. Geology and operating detail and cost data were given. Mining costs were reduced 47 percent during the 7 years of operation.[2]

Beneficiation research on three samples (Mouat, Benbow, and Gish) of low grade, chromite-bearing material from the Stillwater complex were described. Tabling, flotation, high-tension electrostatic separation, and various combinations were investigated to demonstrate that the low-grade materials will respond to conventional concentration techniques that have been successful on higher grade materials from the same locality.[3]

Other published reports showed continued interest in chemical beneficiation, to increase the chromium-iron ratio of chromites. Tests demonstrated the technical feasibility of upgrading Stillwater chromite concentrates by reduction roasting and leaching.[4] In parallel research, conducted on South African chromite, improved results were obtained by use of an oxidizing roast prior to the reduction roasting and leaching.[5]

A patent[6] was issued in the United States for a process to reduce the iron content of chromium ore by heating it in a mixture with magnesium chloride to produce a volatile iron chloride.

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[2] Price, Paul M. Mining Methods and Costs, Mouat Mine, American Chrome Co., Stillwater County, Mont. BuMines Inf. Circ. 8204, 1964, 58 pp.

[3] Sullivan, G. V., and G. F. Workentine. Beneficiating Low-Grade Chromites From the Stillwater Complex, Mont. BuMines Rept. of Inv. 6448, 1964, 29 pp.

[4] Harris, Dwight L. Chemical Upgrading of Stillwater Chromite. Transactions of the Society of Mining Engineers, v. 229, No. 3, September 1964, pp. 267–281.

[5] Jochens, P. R., and D. D. Howat. The Application of the Fluo-Solids Reactor to the Pyrometallurgical Beneficiation of South African Chromite. J. of the South African Institute of Mining and Metallurgy (Johannesburg), v. 65, No. 4, November 1964, pp. 236–253.

[6] Bacon, Frederick E., and Howard M. Dess (assigned to Union Carbide Corp.). Chrome Ore Treating Process. U.S. Pat. 3,144,322. Official Gazette (U.S. Patent Office), v. 805, No. 2, Aug. 11, 1964, p. 490.

Processes for diffusing chromium into the surfaces of metals and alloys were reported[7] to effectively increase oxidation and corrosion resistance. Deposited from a chromium halide or from a packing of chromium-rich powder, the protective coating appeared to offer cost advantages in a broad range of applications where conventional plating might be impractical.

More uniform chromium plating and lower current density was claimed through the use of an unspecified catalyst.[8] A volume[9] on hard chromium plating, published in England, provided a comprehensive treatment of plating techniques.

Research effort by the refractories industry was noteworthy because of improvements achieved and because of the vital role of refractories in all pyrometallurgical operations. The growing use of fusion-cast magnesite-chromite brick was reviewed,[10] and its properties were compared with those of chemically-bonded and direct-bonded brick. Because of higher cost, the fusion-cast refractories were suggested only for selected applications, although their resistance to corrosion, abrasion, and deformation were superior.

The importance of high-purity raw materials for direct-bonded refractories was detailed.[11] In this type of refractory the periclase and chromite particles are bonded directly instead of by a film of silicate.

Investigators concluded that continued effort to overcome room-temperature brittleness and other disadvantages of chromium-base alloys may be justified. Use of carbide dispersion for strengthening and scavenger elements to combat brittleness were investigated.[12]

Alloy system data obtained in investigation of the chromium-gadolinium system by heat treatment, metallography, thermal analysis, and X-ray diffraction were published.[13] The receipients of Bureau of Mines high purity chromium used for research were given.[14]

A method of using a radioisotope, such as carbon 14, for studying the fundamental reactions involved in a chlorination reaction was described. For the first time the competitive reactions of two forms of carbon present during chlorinaton of metal oxide (Cr_2O_3) were studied.[15]

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[7] Baldi, A. L. A Versatile Chromium Diffusion Process. Metal Progress, v. 85, No. 4, April 1964, pp. 109–114.

Trock, Bernard, and George W. Myrick. Chromium Impregnated Steel: A New Muffler Material. Metal Progress, v. 85, No. 4, April 1964, pp. 115–117.

[8] Chemical and Engineering News. New Systems Available for Chrome Platers. V. 42, No. 26, June 29, 1964, p. 40.

[9] Greenwood, J. D. Hard Chromium Plating. Robert Draper, Ltd., 85 Vdney Park Road, Teddington, Middx. 201 pp.

[10] Rauscher, John M., and R. P. Ross. Fusion-Cast Refractories—Steel Plant Applications. Iron and Steel Engineer, v. 41, No. 11, November 1964, pp. 86–94.

[11] Oberschmidt, Leo. Purer Raw Materials Needed for Direct Bonded Refractories. Brick and Clay Record, v. 145, No. 4, October 1964, pp. 46–47.

[12] Ryan, N. E. An Appraisal of Possible Scavenger Elements for Chromium and Chromium Alloys. Journal of the Less Common Elements (the Netherlands). V. 6, No. 1, January 1964, pp. 21–35.

Sims, C. T., and J. W. Clark. Carbide-Strengthened Chromium Alloys. Trans. of the Metallurgical Society of AIME, v. 230, No. 5, August 1964, pp. 1168–1181.

[13] Copeland, M. I., C. E. Armentrout, and H. Kato. The Chromium-Gadolinium System. BuMines Rept. of Inv. 6503, 1964, 9 pp.

[14] Asai, G., and H. Kato. Bureau of Mines Chromium Supplied for Research, July 1953 to July 1961, Including Names of Recipients and Nature of Studies. BuMines Inf. Circ. 8211, 1964, 15 pp.

[15] Brown, Robert R., F. E. Block, and A. W. Henderson. Investigation of Chlorination Reactions Using Carbon 14. BuMines Rept. of Inv. 6402, 1964, 20 pp.

Clays

By James D. Cooper[1]

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CLAY OUTPUT increased by more than 2.5 million tons in 1964, establishing a new record for the second straight year. Output of the individual types of clays also increased, and with exception of fire clays, all established new highs. The largest percentage increases were for fuller's earth, 15 percent, and bentonite, 9 percent. The largest quantity increase was reported for miscellaneous clay which was 2.2 million tons higher than the 1963 figure.

Activity in plant expansions and new plant construction was particularly evident in the bentonite and fuller's earth mining and processing areas. New iron ore pelletizing plants under construction will require additional quantities of Wyoming swelling bentonite. Increased demands for fuller's earth for absorbent uses have resulted in increased activity in the Georgia-Florida producing area.

TABLE 1.—Salient clay and clay products statistics in the United States

(Thousand short tons and thousand dollars)

	1955-59 (average)	1960	1961	1962	1963	1964
Domestic clays sold or used by producers	47,527	49,069	47,389	47,797	[r] 50,135	52,853
Value	$152,308	$162,411	$156,829	$163,012	[r] $180,810	$192,537
Imports for consumption	174	160	156	132	126	137
Value	$3,008	$3,103	$3,055	$2,540	$2,413	$2,638
Exports	468	530	559	617	739	848
Value	$12,526	$13,714	$14,285	$16,855	$21,374	$24,973
Clay refractories, shipments (value)	$187,769	$178,836	$166,628	$166,095	[r] $179,512	$205,267
Clay construction products,[1] shipments (value)	$482,800	$488,500	[r] $481,200	[r] $512,900	[r] $538,600	$567,800

[r] Revised.
[1] Principal products only.

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[1] Commodity specialist, Division of Minerals.

TABLE 2.—Value of clays produced in the United States, by States

(Thousand dollars)

	1963	1964	Kinds of clay produced in 1964
Alabama	[1] $3,003	[1,2] $4,060	Kaolin, fire clay, bentonite, miscellaneous clay.
Arizona	[2,3] 203	[2,3] 213	Fire clay, bentonite, miscellaneous clay.
Arkansas	1,763	2,152	Fire clay, miscellaneous clay.
California	8,031	[4,5] 8,196	Kaolin, ball clay, fire clay, bentonite, fuller's earth, miscellaneous clay.
Colorado	1,334	1,275	Fire clay, bentonite, miscellaneous clay.
Connecticut	339	262	Miscellaneous clay.
Delaware	13	11	Do.
District of Columbia	78	82	Do.
Florida	7,777	8,405	Kaolin, fuller's earth, miscellaneous clay.
Georgia	54,024	58,899	Do.
Idaho	[1,2,3] 15	[1,2,3] 25	Kaolin, fire clay, bentonite, miscellaneous clay.
Illinois	4,368	[5] 4,358	Fire clay, fuller's earth, miscellaneous clay.
Indiana	2,347	2,264	Fire clay, miscellaneous clay.
Iowa	1,405	1,254	Do.
Kansas	1,104	935	Do.
Kentucky	[4] 2,397	[4] 1,801	Ball clay, fire clay, miscellaneous clay.
Louisiana	655	797	Miscellaneous clay.
Maine	55	58	Fire clay, miscellaneous clay.
Maryland	897	[4] 798	Ball clay, fire clay, miscellaneous clay.
Massachusetts	213	174	Miscellaneous clay.
Michigan	2,149	2,592	Do.
Minnesota	[3] 298	[3] 319	Fire clay, miscellaneous clay.
Mississippi	5,968	6,130	Ball clay, fire clay, bentonite, fuller's earth, miscellaneous clay.
Missouri	4,467	4,874	Fire clay, miscellaneous clay.
Montana	[3] 45	[2,3] 59	Fire clay, bentonite, miscellaneous clay.
Nebraska	148	143	Miscellaneous clay.
New Hampshire	[r] 40	40	Do.
New Jersey	1,392	1,441	Fire clay, miscellaneous clay.
New Mexico	140	[3] 167	Do.
New York	2,186	1,993	Miscellaneous clay.
North Carolina	[1] 1,761	[1] 2,064	Kaolin, miscellaneous clay.
North Dakota	[2,6] 10	119	Fire clay, bentonite miscellaneous clay.
Ohio	13,959	14,426	Fire clay, miscellaneous clay.
Oklahoma	[2] 911	[2] 854	Fire clay, bentonite, miscellaneous clay.
Oregon	330	262	Bentonite, miscellaneous clay.
Pennsylvania	[1] 14,717	[1] 15,814	Kaolin, fire clay, miscellaneous clay.
South Carolina	7,589	8,309	Do.
South Dakota	[r] 960	1,076	Bentonite, miscellaneous clay.
Tennessee	[5] 5,248	[5] 5,576	Ball clay, fuller's earth, miscellaneous clay.
Texas	[5] 6,849	[1,5] 6,695	Kaolin, fire clay, bentonite, fuller's earth, miscellaneous clay.
Utah	[1,3] 470	[1,3] 330	Do.
Virginia	1,558	1,614	Miscellaneous clay.
Washington	[3] 123	[3] 119	Fire clay, miscellaneous clay.
West Virginia	2,044	[3] 309	Do.
Wisconsin	140	147	Miscellaneous clay.
Wyoming	[r] 12,385	12,816	Fire clay, bentonite, miscellaneous clay.
Other [7]	4,902	8,230	
Total	[r] 180,810	192,537	
Puerto Rico	158	271	Miscellaneous clay.

[r] Revised.

[1] Value of kaolin included with "Other" to avoid disclosing individual company confidential data.

[2] Value of bentonite included with "Other" to avoid disclosing individual company confidential data.

[3] Value of fire clay included with "Other" to avoid disclosing individual company confidential data.

[4] Value of ball clay included with "Other" to avoid disclosing individual company confidential data.

[5] Value of fuller's earth included with "Other" to avoid disclosing individual company confidential data.

[6] Value of miscellaneous clay included with "Other" to avoid disclosing individual company confidential data.

[7] Includes Hawaii, Nevada and Vermont, and value indicated by footnote 1 through 7.

REVIEW OF DOMESTIC PRODUCTION, PRICES, AND FOREIGN TRADE BY TYPE OF CLAY

KAOLIN

The quantity of kaolin sold or used increased 5 percent, establishing a new production high for the sixth consecutive year.

Paper coating remained the largest single use for kaolin accounting for almost one-third of the total production and together with paper filler accounted for over half of the domestic output. Fillers other than for paper took 21 percent, and refractories took 10 percent. Pottery and stoneware and various miscellaneous uses accounted for the balance.

Imports of kaolin were 117,116 tons, an increase of 9 percent in quantity and 7 percent in value in 1964. Essentially all of the imported kaolin was from the United Kingdom. Mexico, Canada, The Netherlands, and West Germany together supplied about 1 percent of the total quantity representing 2 percent of the value.

Kaolin exports increased appreciably from 111,717 tons in 1963 to 151,725 tons in 1964. The value was $3.3 million in 1963, compared with $4.7 million in 1964. Canada, Mexico, and Japan together received 84 percent of the material.

Kaolin prices published in Oil, Paint and Drug Reporter on December 28, 1964, were as follows: Domestic, dry-ground, calcined, air floated, bags, carlots, works, $45 to $68 per short ton; dry ground, uncalcined, air floated, 99 percent through 325 mesh, Georgia, bags, carlots, works, $17 per ton; water-ground, washed, bags, carlots, works, $22.50 to $51.00 per ton. Imported kaolin, white, lump, bulk, carlots, ex-dock Philadelphia or Portland sold for $23 to $45 per short ton, and imported white kaolin, powdered, bags, carlots, ex-dock sold for $55 to $100 per ton.

United Clay Mines Corp., Trenton, N.J., purchased the Georgia Coating Clay Co., with mine and plant in Twiggs County, near Macon, Ga. The firm owned other kaolin mines and processing facilities in Georgia, Florida, and South Carolina. A new kaolin-sand mining and processing facility was completed in Limestone County, Tex., by Magnet Cove Barium Corp., Ltd., J. M. Huber Corp. announced plans to build a new kaolin processing plant near Wrens, Ga., and to expand the Huber, Ga., plant.

Kaolin bulk samples from newly discovered deposits in New Mexico and Minnesota were undergoing utilization tests to determine if commercial operations were feasible.

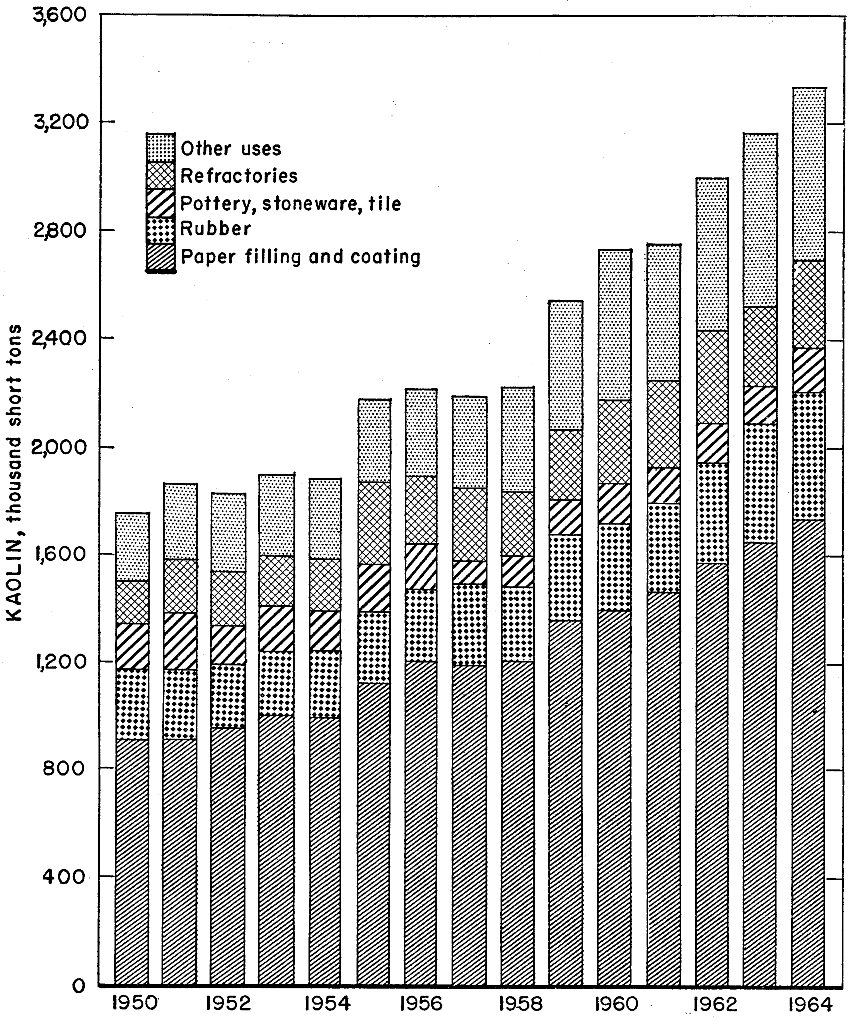

FIGURE 1.—Kaolin sold or used by domestic producers for specified uses.

TABLE 3.—Kaolin sold or used by producers in the United States, by States

Year and State	Sold by producers		Used by producers		Total	
	Short tons	Value	Short tons	Value	Short tons	Value
1955–59 (average)	2,039,184	$33,620,866	232,349	$2,396,670	2,271,533	$36,017,536
1960	2,432,918	43,417,589	297,533	2,259,506	2,730,451	45,677,095
1961	2,471,518	44,877,971	268,298	2,054,899	2,739,816	46,932,870
1962	2,702,920	51,046,599	295,237	2,448,188	2,998,157	53,494,787
1963:						
California	18,941	297,989	---------	---------	18,941	297,989
Florida and North Carolina	33,178	707,123	---------	---------	33,178	707,123
Georgia	2,343,260	49,297,909	146,737	995,974	2,489,997	50,293,883
South Carolina	(1)	(1)	(1)	(1)	484,757	6,622,756
Other States [2]	516,547	6,936,959	104,910	1,534,320	136,700	1,848,523
Total	2,911,926	57,239,980	251,647	2,530,294	3,163,573	59,770,274
1964:						
California	23,312	289,683	---------	---------	23,312	289,683
Florida and North Carolina	35,785	679,808	---------	---------	35,785	679,808
Georgia	2,488,447	53,945,807	95,708	574,072	2,584,155	54,519,879
South Carolina	(1)	(1)	(1)	(1)	521,101	7,166,929
Other States [2]	572,378	7,706,242	115,712	1,411,380	166,989	1,950,693
Total	3,119,922	62,621,540	211,420	1,985,452	3,331,342	64,606,992

[1] Included with "Other States."

[2] Includes States indicated by footnote 1, and Alabama, Connecticut (1963), Idaho, Pennsylvania, Texas, Utah, and Vermont.

TABLE 4.—Georgia kaolin sold or used by producers, by uses

(Thousand short tons and thousand dollars)

Year	China clay, paper clay, etc.	Refractory uses	Total kaolin		
				Value	
	Quantity	Quantity	Quantity	Total	Average per ton
1955–59 (average)	1,492	199	1,691	$28,301	$16.74
1960	1,861	260	2,121	37,822	17.83
1961	1,925	222	2,147	39,557	18.42
1962	2,094	184	2,278	44,655	19.60
1963	2,276	214	2,490	50,294	20.20
1964	2,389	195	2,584	54,520	21.10

BALL CLAY

Tennessee maintained the lead in production of ball clay, with 65 percent of domestic output and 63 percent of the value. Kentucky ranked second, followed by Mississippi, California, and Maryland. Total domestic ball clay production increased by 4 percent in production and value in 1964.

Whiteware, floor and wall tile, and refractories accounted for over 85 percent of all domestic ball clays consumed in 1964. Enamels and building brick required smaller, but significant quantities.

Prices of ball clay as quoted in Oil, Paint and Drug Reporter December 28, 1964, were as follows: Domestic, air-floated, bags, carlots, Tennessee, $18 to $22 per ton; crushed, moisture repellent, bulk, carlots, Tennessee, $8 to $11.25 per ton; imported, airfloated, bags, carlots, Atlantic ports, $46.50 to $48.25 per ton; lump, bulk, Atlantic ports, $31.50 to $37.50 per ton.

Imports of unbeneficiated ball clay totaled 13,036 tons in 1964, a decrease of about 3 percent from the 1963 figure of 13,414 tons. The value was $132,291 in 1964 compared with $140,302 in 1963. The unit value also decreased from $10.46 per ton in 1963 to $10.15 per ton in 1964. Essentially all of the imported material was obtained from the United Kingdom. A small amount, 260 tons, came from Canada. Imports of beneficiated ball clay all from the United Kingdom were 3,016 tons valued at $79,292 in 1964, compared with 1,637 tons valued at $34,553 in 1963. The unit value was $26.29 per ton in 1964 and $21.11 in 1963. In total, ball clay imports rose 7 percent in quantity and 21 percent in value in 1963.

TABLE 5.—Ball clay sold or used by producers in the United States

Year	Short tons	Value	Year	Short tons	Value
1955–59 (average)	430,126	$5,790,436	1962	486,936	$6,810,441
1960	444,369	5,977,963	1963	547,668	7,541,471
1961	444,593	6,090,091	1964	567,315	7,829,841

FIRE CLAY

The total quantity of fire clay sold or used by producers increased 2 percent in 1964, and the reported value was 4 percent higher. The amount used in refractories, which increased by 4 percent, represented 49 percent of the output, compared with only 45 percent in 1963. Ohio, Pennsylvania, and Missouri, in the order named, were the leading fire clay producing States, with 57 percent of the total, compared with 55 percent in 1963.

Refractories constituted the major use of fire clay, accounting for half the total quantity sold or used. Heavy clay products consumed 46 percent of the total in 1964 compared with 50 percent in 1963. Other uses, including chemicals, cement, pottery and stoneware accounted for 5 percent of the 1964 output.

Exports of fire clay were 246,796 tons, down 7 percent from the 1963 figure of 264,440 tons. However, the value increased 8 percent from $5,184,000 in 1963 to $5,596,000 in 1964. The average unit value was $22.67 per ton in 1964, compared with $19.60 in 1963. The principal recipient countries were Canada, Mexico, and Japan, which accounted for 80 percent of the quantity and 54 percent of the value.

Two plants for production of tar bonded refractories were under construction in the latter part of 1964, one by A. P. Green Fire Brick Co., at Detroit, Mich., and the other by Ohio Fire Brick Co., at Oak Hill, Ohio. The Carrol Clay Co., Carrolton, Ohio, a producer of pouring pit refractories, was acquired by Howe Sound Co.

TABLE 6.—Fire clay, including stoneware clay,[1] sold or used by producers in the United States, by States

Year and State	Sold by producers		Used by producers		Total	
	Short tons	Value	Short tons	Value	Short tons	Value
1955–59 (average)	2,862,916	$9,018,443	7,560,660	$37,539,813	10,423,576	$46,558,256
1960	2,489,945	8,840,604	7,425,427	36,390,257	9,915,372	45,230,861
1961	2,067,833	7,084,999	6,621,884	31,716,800	8,689,717	38,801,799
1962	2,034,332	6,873,689	6,030,716	28,934,226	8,065,048	35,807,915
1963:						
Alabama	(2)	(2)	(2)	(2)	220,582	1,755,483
Arkansas	—	—	194,498	1,190,100	194,498	1,190,100
California	(2)	(2)	(2)	(2)	531,390	1,920,589
Colorado	98,306	371,644	95,761	329,542	194,067	701,186
Illinois	(2)	(2)	(2)	(2)	331,836	1,711,576
Indiana	(2)	(2)	(2)	(2)	447,539	723,676
Iowa	(2)	(2)	(2)	(2)	31,455	56,841
Kentucky	67,072	374,240	144,229	1,014,259	211,301	1,388,499
Maine	—	—	27	79	27	79
Mississippi	591	2,955	156,873	330,253	157,464	333,208
Missouri	(2)	(2)	(2)	(2)	849,702	3,567,900
New Jersey	(2)	(2)	(2)	(2)	106,809	900,242
North Dakota	—	—	5,200	10,400	5,200	10,400
Ohio	775,382	2,389,398	1,477,603	8,329,628	2,252,985	10,719,026
Oklahoma	—	—	449	4,490	449	4,490
Pennsylvania	545,937	1,611,303	958,633	8,300,535	1,504,570	9,911,838
Texas	4,962	45,393	802,853	2,008,314	807,815	2,053,707
Other States[3]	962,464	4,597,930	2,099,334	8,647,407	542,485	2,609,030
Total	2,454,714	9,392,863	5,935,460	30,165,007	8,390,174	39,557,870
1964:						
Alabama	(2)	(2)	(2)	(2)	387,207	2,580,924
Arkansas	—	—	242,360	1,515,893	242,360	1,515,893
California	73,156	257,289	472,880	1,776,396	546,036	2,033,685
Colorado	85,062	295,390	92,107	393,562	177,169	688,952
Illinois	147,552	1,343,216	143,224	550,316	290,776	1,893,532
Indiana	(2)	(2)	(2)	(2)	376,361	644,182
Iowa	17,146	19,280	(2)	(2)	17,146	19,280
Kansas	—	—	98,748	240,341	98,748	240,341
Kentucky	25,590	142,286	78,746	569,510	104,336	711,796
Maine	—	—	27	79	27	79
Maryland	(2)	(2)	(2)	(2)	29,204	102,667
Mississippi	300	1,500	207,335	428,835	207,635	430,335
Missouri	(2)	(2)	(2)	(2)	1,002,068	3,905,166
New Jersey	(2)	(2)	(2)	(2)	120,518	958,030
Ohio	912,617	2,449,473	1,383,571	8,479,262	2,296,188	10,928,735
Oklahoma	—	—	380	3,800	380	3,800
Pennsylvania	554,082	1,561,328	1,030,031	8,581,686	1,584,113	10,143,014
South Carolina	—	—	1,024	9,000	1,024	9,000
Texas	(2)	(2)	(2)	(2)	666,061	1,814,526
Other States[3]	799,597	3,636,082	2,183,155	8,738,282	401,333	2,368,869
Total	2,615,102	9,705,844	5,933,588	31,286,962	8,548,690	40,992,806

[1] Includes stoneware clay as follows: 1955–59 (average), 44,105; 1960, 27,470; 1961, 24,554; 1962, 57,820; 1963, 44,798; 1964, 45,679 tons.

[2] Included with "Other States."

[3] Includes States indicated by footnote 2 and Arizona, Idaho, Kansas (1963), Maryland (1963), Minnesota, Montana, Nevada (1963), New Mexico, North Dakota (1963), Utah, Washington, West Virginia, and Wyoming.

BENTONITE

Bentonite production increased by about 9 percent due in large part to the rapidly expanding use in iron ore pelletizing. This use accounted for 378,274 tons in 1964 and represented 22 percent of the total bentonite sold or used. Bentonite used in foundries and steelworks remained the largest use category, with 31 percent, followed by drilling mud with 25 percent. Other significant uses included absorbents, oil filtering and clarifying, and sealing ponds and reservoirs.

Bentonite prices at the end of 1964 as quoted in Oil, Paint and Drug Reporter were unchanged from yearend prices in 1963. They were as follows: 200 mesh, in bags, carlots, f.o.b. mines (Wyoming), $14 per short ton; imported, Italian, white, high-gel, in bags, 5-ton lots, ex warehouse, $97 per ton.

The average value of bentonite sold or used by producers in 1964 was $11.22 per ton, down appreciably from the value of $11.70 per ton in 1963.

Chicago was a major port for shipments of Wyoming bentonite to Canada for use as binder in pelletizing Quebec and Labrador iron ore. As much as 50,000 tons may have gone through the port in 1964, and the quantity should increase as new pelletizing plants are completed. A $400,000 plant for production of 800 tons per day of swelling bentonite was completed near Casper, Wyo., by Black Hills Bentonite Co. The firm's Moorcroft plant was closed.

Bentonite imports, almost evenly divided between Canada and Italy, totaled 179 tons valued at $5,903. Unit value of the Italian bentonite was more than double that of the Canadian material.

American Colloid Co. produced bentonite for foundry sand and other uses at a new mine and processing plant near Sandy Ridge, Lowndes County, Ala.

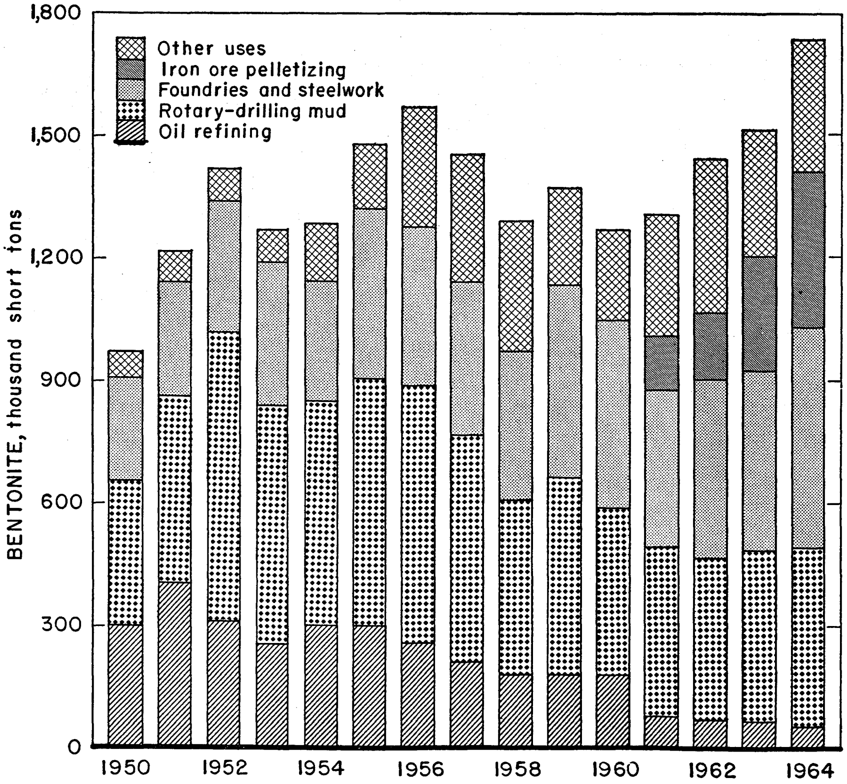

FIGURE 2.—Bentonite sold or used by domestic producers for specified uses.

TABLE 7.—Bentonite sold or used by producers in the United States, by States

Year and State	Short tons	Value
1955–59 (average)	1,433,076	$16,919,815
1960	1,268,800	15,004,757
1961	1,307,191	15,224,347
1962	1,444,135	16,254,215
1963:		
Colorado	931	6,051
Mississippi	280,077	3,480,643
Texas	120,480	1,366,596
Utah	6,711	90,515
Washington	100	1,000
Wyoming [r]	1,065,374	12,187,984
Other States [r][1]	110,843	1,403,440
Total	1,584,516	18,536,229
1964:		
California	20,817	$366,120
Colorado	1,270	12,956
Mississippi	269,783	3,352,472
Oregon	718	8,613
Texas	111,016	1,294,516
Utah	6,059	81,867
Wyoming	1,172,103	12,648,835
Other States [1]	147,737	1,648,017
Total	1,729,503	19,413,396

[r] Revised.

[1] Includes Arizona, California (1963), Idaho, Montana (1964), Nevada, North Dakota, Oklahoma, Oregon (1963), South Dakota.

FULLER'S EARTH

The quantity of fuller's earth sold or used by producers increased 15 percent. Absorbent and insecticide-fungicide carrier uses together accounted for 75 percent of the 1964 output compared with 71 percent in 1963. Other uses remained at about the 1963 level.

The average value for fuller's earth in 1964 was $23.09 per ton, down slightly from the 1963 figure of $23.27, but still the highest unit value of all clay types. Prices for fuller's earth are not quoted in the trade journals.

Imports of fuller's earth in 1964 were 256 tons valued at $5,449 all from Surinam and the United Kingdom. Export data for fuller's earth were not reported separately in 1964, but were included with other clays.

An expansion of fuller's earth processing facilities was underway at the Havana, Fla., plant of Magnet Cove Barium Corp. Also in Florida, Minerals and Chemicals Phillip Corp. was increasing the production capacity of the Gadsden County plant. A new fuller's earth mining and processing plant was under construction at Ocklocknee, Ga.

TABLE 8.—Fuller's earth sold or used by producers in the United States, by States

Year and State	Short tons	Value
1955–59 (average)	384,208	$8,238,518
1960	408,325	9,161,658
1961	422,181	9,518,238
1962	409,989	9,377,355
1963:		
Florida and Georgia	415,458	10,060,750
Utah	3,167	42,756
Other States [1]	63,192	1,107,112
Total	481,817	11,210,618
1964:		
Florida and Georgia	455,701	$11,111,072
Utah	3,172	44,919
Other States [1]	93,013	1,586,906
Total	551,886	12,742,897

[1] Includes California, Illinois, Mississippi, Nevada, Tennessee, and Texas.

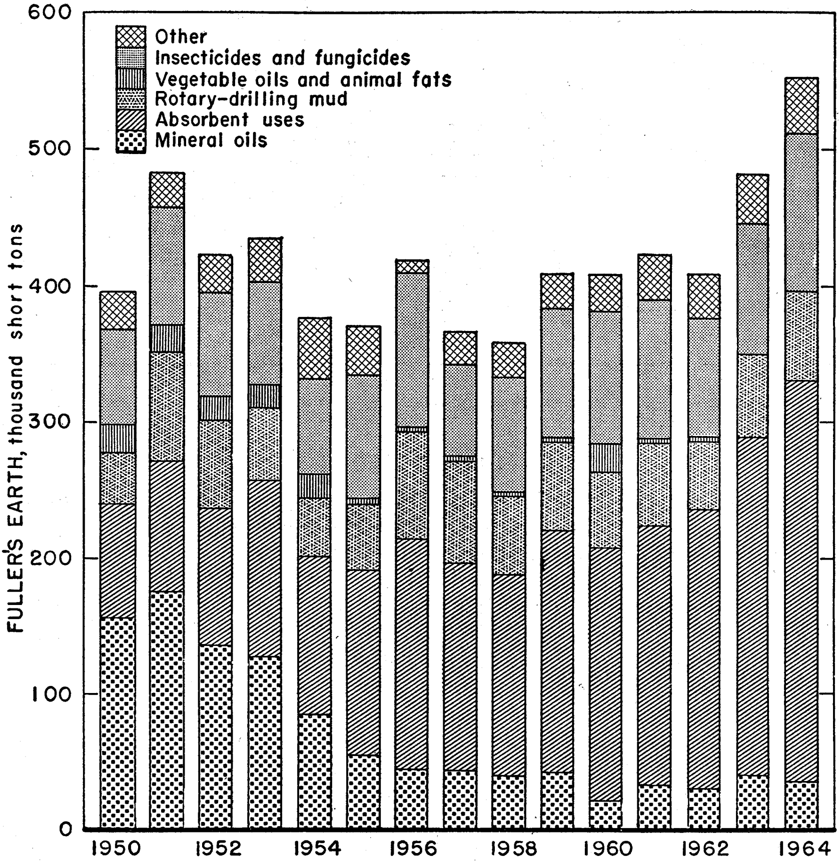

FIGURE 3.—Fuller's earth sold or used by producers for specified uses.

MISCELLANEOUS CLAY AND SHALE

The large quantities of clay and shale used in heavy clay construction products, cement, and lightweight aggregates are included in the category of Miscellaneous Clay and Shale. Smaller quantities of miscellaneous clay find their way into pottery, refractories, fillers, and various other products.

Production in 1964 was up 6 percent in quantity and value, establishing new record highs. The unit value was $1.23 per ton, no change from that of 1963. Largest individual increases were those quantities used for clay construction products, up 8 percent, and for cement, up 6 percent.

Miscellaneous clay and shale is usually mined by manufacturers of the various clay products, and only a relatively small quantity is sold in the raw state. Captive production was 96 percent of the total output in 1964, compared with 97 percent in 1963.

Export data for fire clay and kaolin are reported individually and are included elsewhere in the Clays chapter, but for all other clays, exports are reported in a blanket category. Exports of clays not individually classified in 1964 totaled 449,537 tons valued at $14,706,140, compared with 363,191 tons valued at $12,875,481 in 1963. The unit value was $32.71 per ton in 1964, an appreciable drop from the unit value of $35.45 in 1963. Canada received 40 percent of the total, United Kingdom 8 percent, Australia 7 percent, and Mexico and Japan each 5 percent. The remaining 35 percent went to more than 75 countries throughout the world, in quantities ranging from 4 tons to 16,480 tons.

TABLE 9.—Miscellaneous clay, including shale and slip clay sold or used by producers in the United States, by States

Year and State	Sold by producers		Used by producers		Total	
	Short tons	Value	Short tons	Value	Short tons	Value
1955–59 (average)	1,102,928	$1,705,026	31,482,104	$37,077,822	32,585,032	$38,782,848
1960	1,457,387	2,101,850	32,842,407	39,263,112	34,299,794	41,364,962
1961	916,772	1,035,824	32,871,157	39,227,174	33,787,929	40,262,998
1962	957,201	1,003,061	33,434,860	40,262,516	34,392,061	41,265,577
1963:						
Alabama	(1)	(1)	(1)	(1)	1,386,525	1,247,940
Arizona	----------	----------	162,395	203,194	162,395	203,194
Arkansas	----------	----------	574,161	572,540	574,161	572,540
California	128,922	234,341	2,671,978	4,931,078	2,800,900	5,165,419
Colorado	(1)	(1)	(1)	(1)	491,138	626,659
Connecticut	(1)	(1)	(1)	(1)	189,344	338,560
Delaware	----------	----------	12,700	12,700	12,700	12,700
District of Columbia	----------	----------	77,858	77,858	77,858	77,858
Georgia	----------	----------	1,581,337	771,229	1,581,337	771,22
Idaho	----------	----------	30,900	15,300	30,900	15,300
Illinois	(1)	(1)	(1)	(1)	1,617,406	2,656,156
Indiana	(1)	(1)	(1)	(1)	1,098,016	1,623,411
Iowa	(1)	(1)	(1)	(1)	1,032,551	1,347,994
Kentucky	----------	----------	772,433	1,008,510	772,433	1,008,510
Louisiana	----------	----------	655,076	655,076	655,076	655,076
Maine	----------	----------	42,365	55,250	42,365	55,250
Maryland	(1)	(1)	(1)	(1)	551,738	656,198
Massachusetts	----------	----------	157,442	213,242	157,442	213,242
Michigan	----------	----------	1,958,222	2,148,548	1,958,222	2,148,548
Minnesota	----------	----------	198,743	298,140	198,743	298,140
Mississippi	----------	----------	725,464	726,762	725,464	726,762
Missouri	(1)	(1)	(1)	(1)	896,676	899,180
Montana	----------	----------	37,850	45,013	37,850	45,013
Nebraska	----------	----------	147,807	147,807	147,807	147,807
New Hampshire	----------	----------	r 46,875	r 40,375	r 46,875	r 40,375
New Jersey	----------	----------	390,994	491,530	390,994	491,530
New York	(1)	(1)	(1)	(1)	1,597,973	2,186,322
North Carolina	----------	----------	2,735,290	1,761,100	2,735,290	1,761,100
Ohio	159,745	157,255	2,428,286	3,082,466	2,588,031	3,239,721
Oklahoma	(1)	(1)	(1)	(1)	897,150	907,050
Pennsylvania	(1)	(1)	(1)	(1)	1,686,035	4,805,392
South Carolina	----------	----------	1,005,942	965,893	1,005,942	965,893
Tennessee	(1)	(1)	(1)	(1)	882,452	570,794
Texas	17,500	17,500	3,253,205	3,411,625	3,270,705	3,429,125
Utah	(1)	(1)	(1)	(1)	114,652	336,555
Virginia	----------	----------	1,410,098	1,558,327	1,410,098	1,558,327
Washington	925	463	132,596	121,511	133,521	121,974
Wisconsin	----------	----------	111,169	140,262	111,169	140,262
Undistributed [2]	734,731	780,504	13,605,245	19,548,965	1,898,320	2,127,258
Total	1,041,823	1,190,063	r 34,926,431	r 43,004,301	r 35,968,254	r 44,194,364
1964:						
Alabama	(1)	(1)	(1)	(1)	1,603,854	1,478,862
Arizona	----------	----------	167,365	212,708	167,365	212,708
Arkansas	----------	----------	649,266	636,241	649,266	636,241
California	105,061	199,828	2,955,736	5,306,534	3,060,797	5,506,362
Colorado	(1)	(1)	(1)	(1)	379,470	573,108

See footnotes at end of table.

TABLE 9.—Miscellaneous clay, including shale and slip clay sold or used by producers in the United States, by States—Continued

Year and State	Sold by producers		Used by producers		Total	
	Short tons	Value	Short tons	Value	Short tons	Value
1964—Continued						
Connecticut	(1)	(1)	(1)	(1)	211,621	262,400
Delaware	-----	-----	11,300	11,300	11,300	11,300
District of Columbia	-----	-----	82,150	82,150	82,150	82,150
Georgia	-----	-----	1,621,263	973,821	1,621,263	973,821
Idaho	(1)	(1)	(1)	(1)	29,077	24,784
Illinois	209,449	217,449	1,506,600	2,247,238	1,716,049	2,464,687
Indiana	178,699	190,245	990,266	1,429,841	1,168,965	1,620,086
Iowa	(1)	(1)	(1)	(1)	990,863	1,234,888
Kansas	-----	-----	685,900	694,768	685,900	694,768
Kentucky	-----	-----	815,846	1,089,557	815,846	1,089,557
Louisiana	(1)	(1)	(1)	(1)	779,679	796,832
Maine	-----	-----	44,620	57,740	44,620	57,740
Maryland	(1)	(1)	(1)	(1)	605,375	694,933
Massachusetts	-----	-----	138,214	174,214	138,214	174,214
Michigan	-----	-----	2,385,365	2,592,279	2,385,365	2,592,279
Minnesota	-----	-----	212,616	318,962	212,616	318,962
Mississippi	7,000	7,000	767,796	767,796	774,796	774,796
Missouri	(1)	(1)	(1)	(1)	963,842	969,281
Montana	-----	-----	48,962	58,588	48,962	58,588
Nebraska	-----	-----	142,891	142,891	142,891	142,891
New Hampshire	-----	-----	45,620	39,820	45,620	39,820
New Jersey	-----	-----	378,997	482,709	378,997	482,709
New Mexico	(1)	(1)	(1)	(1)	104,145	167,128
New York	(1)	(1)	(1)	(1)	1,499,268	1,993,463
North Carolina	-----	-----	3,199,177	2,064,087	3,199,177	2,064,087
Ohio	216,526	214,340	2,492,185	3,282,529	2,708,711	3,496,869
Oklahoma	(1)	(1)	(1)	(1)	834,807	850,307
Oregon	(1)	(1)	(1)	(1)	194,919	253,726
Pennsylvania	105,895	78,428	1,497,092	5,592,501	1,602,987	5,670,929
South Carolina	-----	-----	1,220,678	1,133,401	1,220,678	1,133,401
Tennessee	-----	-----	939,468	643,241	939,468	643,241
Texas	(1)	(1)	(1)	(1)	3,378,918	3,585,917
Utah	4,436	6,676	113,512	196,542	117,948	203,218
Virginia	-----	-----	1,440,385	1,613,523	1,440,385	1,613,523
Washington	990	495	126,892	118,911	127,882	119,406
West Virginia	-----	-----	261,498	308,522	261,498	308,522
Wisconsin	-----	-----	119,156	146,670	119,156	146,670
Undistributed [2]	537,814	696,129	11,698,075	12,922,903	660,051	733,403
Total	1,365,870	1,610,590	36,758,891	45,341,987	38,124,761	46,952,577

[r] Revised.

[1] Included with "Undistributed."

[2] Includes States indicated by footnote 1 and Florida, Hawaii, Kansas (1963), Nevada (1963), New Mexico (1963), North Dakota, Oregon (1963), South Dakota, Vermont, West Virginia, and Wyoming.

CONSUMPTION AND USES

Heavy clay construction products accounted for 45 percent of all clay consumption in 1964, followed by cement, 21 percent; lightweight aggregates, 13 percent; and refractories, 10 percent. With exception of lightweight aggregates which required slightly less clay and shale in 1964, the quantities consumed in all the major use categories increased.

The most significant increases for individual types of clay were for bentonite used in iron ore pelletizing, up 35 percent, and fuller's earth in absorbents, up 19 percent over 1963.

Refractories.—Shipments of clay refractories increased about 9 percent in total quantity in 1964, while the value was 15 percent greater, due to increased use of the higher heat duty refractory clay products. Shipments of standard fire clay brick other than the superduty-type declined, whereas shipments of all other categories of clay

TABLE 10.—Clays sold or used by producers in the United States in 1964, by kinds

Uses	Kaolin	Ball clay	Fire clay and stoneware clay	Bentonite	Fuller's earth	Miscellaneous clay including slip clay	Total
Pottery and stoneware:							
Whiteware, etc	[1] 148, 721	[1] 292, 508	-----	-----	-----	-----	[1] 441, 229
Stoneware, art pottery, flower pots, and glaze slip	(1)	(1)	45, 679	-----	-----	76, 097	[1] 121, 776
Total	148, 721	292, 508	45, 679	-----	-----	76, 097	563, 005
Floor and wall tile	16, 553	114, 785	172, 762	-----	-----	144, 633	448, 733
Refractories:							
Firebrick and block	285, 033	(2)	2, 990, 442	-----	-----	(2)	3, 318, 842
Bauxite, high-alumina brick	-----	-----	114, 004	-----	-----	-----	114, 004
Fire-clay mortar	(2)	(2)	159, 360	(3)	-----	(2)	181, 409
Clay crucibles	-----	-----	(2)	-----	-----	(2)	(2)
Glass refractories	(2)	(2)	-----	-----	-----	(2)	(2)
Zinc retorts and condensers	-----	-----	(2)	-----	-----	-----	(2)
Foundries and steelworks	(2)	-----	645, 495	[3] 537, 025	-----	(2)	1, 191, 713
Saggers, pins, stilts, and wads	9, 691	(2)	(2)	-----	-----	-----	53, 106
Other refractories	32, 769	87, 744	261, 898	(3)	-----	24, 024	288, 411
Total	327, 493	87, 744	4, 171, 199	537, 025	-----	24, 024	5, 147, 485
Heavy clay products:							
Building brick, paving brick, drain tile, sewer pipe, and kindred products	-----	(4)	3, 964, 399	-----	-----	19, 821, 623	[5] 23, 786, 022
Architectural terra cotta	3, 450	-----	3, 443	-----	-----	-----	6, 893
Lightweight aggregates	-----	-----	-----	-----	-----	6, 752, 893	6, 752, 893
Filler:							
Paper filling	705, 071	-----	-----	(4)	-----	-----	[6] 705, 071
Paper coating	1, 027, 597	-----	-----	-----	(4)	-----	[6] 1, 027, 597
Rubber	467, 807	-----	-----	-----	-----	-----	467, 807
Paint	65, 223	-----	-----	-----	-----	-----	65, 223
Fertilizers	32, 662	-----	(2)	-----	-----	(2)	[6] 32, 662
Insecticides and fungicides	19, 836	-----	6, 157	6, 192	116, 344	(2)	[6] 148, 529
Other fillers	127, 673	(4)	4, 802	(4)	(4)	5, 583	152, 040
Total	2, 445, 869	(4)	10, 959	6, 192	116, 344	5, 583	2, 598, 929
Portland and other hydraulic cements	115, 045	-----	58, 478	(4)	-----	10, 977, 047	[5] 11, 150, 570
Miscellaneous:							
Filtering, decolorizing and clarifying	-----	-----	-----	55, 609	36, 790	-----	92, 399
Rotary-drilling mud	-----	-----	6, 759	434, 754	64, 399	7, 429	513, 341
Chemicals	(4)	-----	(4)	(4)	(4)	-----	134, 197
Absorbent uses	(4)	-----	(4)	(4)	295, 278	(4)	[5] 295, 278
Exports	139, 673	-----	(4)	(4)	(4)	(4)	231, 588
Enameling	(4)	19, 550	-----	(4)	-----	-----	[5] 19, 550
Catalysts (oil refining)	(4)	-----	-----	(4)	-----	-----	(4)
Pelletizing:							
Iron ore	-----	-----	-----	378, 274	-----	-----	378, 274
Other	-----	-----	-----	14, 435	(4)	-----	[5] 14, 435
Reservoir, pond and ditch lining	-----	-----	-----	25, 840	-----	-----	25, 840
Other uses	134, 538	52, 728	115, 012	277, 374	39, 075	315, 432	694, 065
Total	274, 211	72, 278	121, 771	1, 186, 286	435, 542	322, 861	2, 398, 967
Grand total:							
1964	3, 331, 342	567, 315	8, 548, 690	1, 729, 503	551, 886	38, 124, 761	52, 853, 497
1963	3, 163, 573	547, 668	8, 390, 174	1, 584, 516	481, 817	[r] 35, 968, 254	[r] 50, 136, 002

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[r] Revised.

[1] Some stoneware, art pottery, etc., included with whiteware.

[2] Included with "Other."

[3] Some "Fire clay mortar" and "Other refractories" included with foundaries.

[4] Included with miscellaneous "Other uses."

[5] Incomplete figure; remainder included with miscellaneous "Other uses."

[6] Incomplete figure; remainder included with "Other."

refractory brick increased. Nonclay refractories shipments increased more than 10 percent in quantity and 16 percent in value over those of 1963.

Major changes in refractories requirements due in large part to technologic advances in steel production, continued in 1964. Higher operating temperatures and more corrosive furnace conditions together with demands for longer life refractories needed to reduce down time and maintenance costs are major factors in the changing use pattern.

TABLE 11.—Shipments of refractories in the United States, by kinds

Product	Unit of quantity	Shipments			
		1963		1964	
		Quantity	Value (thousands)	Quantity	Value (thousands)
Clay refractories:					
Fire-clay (including semisilica) brick and shapes, except superduty.	1,000 9-inch equivalent.	[r] 276,699	$44,161	289,955	$45,863
Superduty fire-clay brick and shapes	do.	67,497	19,185	72,307	21,160
High-alumina brick and shapes (50 percent Al_2O_3 and over) made substantially of calcined diaspore or bauxite.[1]	do.	32,596	15,373	38,443	19,150
Insulating firebrick and shapes	do.	44,302	11,337	54,330	13,443
Ladle brick	do.	184,961	20,705	224,035	25,827
Sleeves, nozzles, runner brick and tuyeres	do.	42,457	9,361	48,800	11,590
Glasshouse pots, tank blocks, feeder parts and upper structure shapes used only for glass tanks.[1]	Short ton	13,516	4,391	12,667	4,291
Hot-top refractories	do.	61,621	4,429	73,345	5,219
Clay-kiln furniture, radiant-heater elements, potters' supplies, and other miscellaneous shaped refractory items.		NA	[r] 7,508	NA	8,544
Refractory bonding mortars, air-setting (wet and dry types).[2]	Short ton	53,503	[r] 6,290	59,485	7,051
Refractory bonding mortars, except air-setting types.[2]	do.	[r] 9,115	[r] 883	11,948	1,189
Ground crude fire clay, high-alumina clay and silica fire clay.	do.	[r] 324,907	[r] 3,232	351,050	3,458
Plastic refractories and ramming mixes [1]	do.	165,668	13,638	180,659	15,718
Castable refractories (hydraulic-setting)	do.	120,971	12,075	137,846	14,067
Insulating castable refractories (hydraulic-setting).	do.	18,310	2,338	26,394	3,370
Other clay refractory materials sold in lump or ground form.[3] [4]	do.	[r] 202,936	4,606	206,608	5,327
Total clay refractories		XX	[r] 179,512	XX	205,267
Nonclay refractories:					
Silica brick and shapes	1,000 9-inch equivalent.	119,290	22,499	127,781	23,981
Magnesite and magnesite-chrome brick and shapes (magnesite predominating) (excluding molten cast and fused magnesia).	do.	[r] 79,456	[r] 69,952	104,504	94,085
Chrome and chrome-magnesite brick and shapes (chrome predominating) (excluding molten cast).	do.	35,292	27,906	39,490	30,550
Graphite crucibles, retorts, stopper heads, and other shaped refractories, containing natural graphite.	Short ton	13,024	10,077	15,073	11,572
Mullite brick and shapes made predominantly of kyanite, sillimanite, andalusite or synthetic mullite (excluding molten-cast).	1,000 9-inch equivalent.	[r] 5,929	7,058	5,589	7,148
Extra-high alumina brick and shapes made predominantly of fused bauxite, fused or dense-sintered alumina (excluding molten-cast).	do.	3,173	5,661	3,881	7,779
Silicon carbide brick and shapes made predominantly of silicon carbide.	do.	[r] 2,954	9,552	3,298	11,178
Zircon and zirconia brick and shapes made predominantly of either of these materials.	do.	953	3,867	947	3,814
Forsterite, pyrophyllite, molten-cast, and other nonclay brick and shapes.		NA	30,314	NA	30,394

See footnotes at end of table.

TABLE 11.—Shipments of refractories in the United States, by kinds—Con.

Product	Unit of quantity	Shipments			
		1963		1964	
		Quantity	Value (thousands)	Quantity	Value (thousands)
Nonclay refractories—Continued					
Mortars:					
Basic bonding mortars (magnesite or chrome predominating).	Short ton	223,999	19,655	118,861	10,195
Other nonclay refractory mortars	do			138,866	13,827
Nonclay refractory castables (hydraulic-setting).	do	13,255	2,060	20,825	3,194
Plastic refractories and ramming mixes (wet and dry types):					
Basic (magnesite, dolomite, or chrome predominating).	do	182,695	21,979	153,172	16,292
Other nonclay plastic refractories and ramming mixes.	do			32,514	7,651
Dead-burned magnesia or magnesite	do	198,002	12,947	250,049	15,175
Carbon refractories; brick, blocks, and shapes, excluding those containing natural graphite.	do	233,140	21,229	277,125	24,090
Nonclay gunning mixes	do				
Other nonclay refractory materials sold in lump or ground form.[3]	do				
Total nonclay refractories	XX	XX	[r] 264,756	XX	310,925
Grand total refractories	XX	XX	[r] 444,268	XX	516,192

[r] Revised.

NA Not available. XX Not applicable.

[1] Excludes data for mullite and extra-high alumina refractories. These products are included with mullite and extra-high alumina brick and shapes in the nonclay refractories section.

[2] Includes data for bonding mortars which contain up to 60 percent Al_2O_3, dry basis. Bonding mortars which contain more than 60 percent Al_2O_3 dry basis are included in the nonclay refractories section.

[3] Represents only shipments by establishments classified in "manufacturing" industries, and excludes shipments to refractory producers for the manufacture of brick and other refractories.

[4] Includes data for calcined clay, ground brick, and siliceous and other gunning mixes.

Heavy Clay Products.—The largest use for clay and shale was in the manufacture of clay construction products, principally brick, tile, and clay sewer pipe. Production of brick, sewer pipe, and floor and wall tile increased substantially while production of structural and facing tile declined. Activity in the clay products manufacturing industries was high with construction of new plants, expansion and modernization of older facilities, and diversification through purchase or merger.

New plants were under construction by American Olean Tile Division of National Gypsum Co., at Quakertown, Pa.; Chattahoochie Brick Co., at Atlanta, Ga.; Streator Clay Pipe Co., at Carol Stream, Ill.; and Belden Brick Co., at Sugar Creek, Ohio.

Expansion plans were announced or underway by New Jersey Shale Brick and Tile Co., Sommersville, N.J.; Merry Brothers Brick & Tile Co., Augusta, Ga.; Burns Brick Co., Macon, Ga.; Pine Hall Brick and Pipe Co., Winston-Salem, N.C.; General Shale Products Co., Knoxville, Tenn.; Marshall Brick Co., Marshall, Tex.; and Port Costa Clay Products Co., Port Costa, Calif. The Port Costa company was purchased by Homestake Mining Co. in 1964.

Resco Products, Inc., of Philadelphia acquired the Cresent Brick Co., New Cumberland, W. Va., and W. S. Dickey Clay Manufacturing Co., of Kansas City, Mo., purchased the Lehigh Sewer Pipe & Tile Co., Lehigh, Iowa.

Lightweight Clay and Shale Aggregates.—The quantity of clay and shale used for production of lightweight aggregates in 1964 was 6,753,000 tons, compared with 6,797,000 tons in 1963. A total of 48 firms with 65 plants reported production during the year. The output of five firms which reported 703,000 tons of slate used for manufacturing expanded aggregates is not included with the clay and shale figure.

A large expanded shale production plant was completed at Woodsboro, Frederick County, Md., near the end of the year by Lehigh Portland Cement Co. Plans for new plants were announced by Vulcan Materials Co. in Jefferson County, Ala., near Bessemer, and by Port Costa Clay Products Co., in Contra Costa County, Calif. Also in California, Pacific Vegetable Oil Co. of Richmond announced it was considering diversification into the lightweight clay products field. Carter-Waters Corp. announced it would double the production capacity of the Centerville, Iowa, plant to 140,000 cubic yards per year. Carolina Solite Corp. purchased 300 acres near Lillington, N.C., and planned to build a lightweight aggregate plant employing about 100 men.

TABLE 12.—Shipments of principal structural clay products in the United States

Product	1955-59 (average)	1960	1961	1962	1963	1964
Unglazed brick (building) 1,000 standard brick	6,988,260	6,502,200	6,427,600	6,913,100	7,405,000	7,743,800
Value thousands	$225,080	$223,500	$225,300	$246,500	[r]$267,100	$284,600
Unglazed structural tile short tons	677,940	488,200	476,000	422,900	[r]342,800	311,400
Value thousands	$9,440	$7,800	$7,400	$6,600	$5,600	$5,400
Vitrified clay sewer pipe and fittings short tons	1,884,000	1,854,500	[r]1,763,800	[r]1,743,600	[r]1,771,900	1,837,200
Value thousands	$87,400	$94,800	[r]$90,500	[r]$91,000	[r]$97,700	$104,000
Facing tile, ceramic glazed, including glazed brick 1,000-brick equivalent	406,940	369,500	388,000	370,300	[r]352,900	332,700
Value thousands	$30,820	$30,300	$31,600	$31,100	[r]$28,600	$27,500
Facing tile, unglazed and salt glazed 1,000-tile, 8- by 5- by 12-inch, equivalent	21,560	12,300	11,200	10,800	[r]8,500	6,900
Value thousands	$3,380	$2,600	$2,100	$2,200	[r]$1,700	$1,500
Clay floor and wall tile and accessories 1,000 square feet including quarry tile	228,060	233,000	228,400	253,100	[r]267,100	286,000
Value thousands	$126,680	$129,500	$124,300	$135,500	[r]$137,900	$144,800
Total value do	$482,800	$488,500	[r]$481,200	[r]$512,900	[r]$538,600	$567,800

[r] Revised.

Source: Bureau of the Census, U.S. Department of Commerce.

WORLD REVIEW

Algeria.—A kaolin deposit in the Diebel Diebar Mountains was examined by Bulgarian engineers, and the Algerian Government planned to exploit the material.[2] Fuller's earth production was 54,278 tons in 1964.

Austria.—Bentonite output in 1964 was 3,440 tons.

Bolivia.—A refractory brick plant was completed at the Oruro tin foundry. In addition to 50 workers in the plant others are employed to produce the refractory raw materials. Most of the refractories required at the foundry were furnished by the new plant at a cost less than one-third that of imported products.[3]

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[2] Bureau of Mines. Mineral Trade Notes. V. 58, No. 2, February 1964, p. 9.

[3] Bureau of Mines. Mineral Trade Notes. V. 58, No. 4, April 1964, p. 10.

TABLE 13.—World production of china clay by countries [1]

(Short tons)

Country [1]	1955–59 (average)	1960	1961	1962	1963	1964 [p]
North America:						
Mexico	[2] 66,862	81,544	66,910	NA	51,325	70,796
United States	2,271,533	2,730,451	2,739,816	2,998,157	3,163,573	3,331,342
South America:						
Argentina	32,913	45,229	40,141	52,426	34,284	45,614
Chile	[e] 5,840	8,598	15,599	33,581	40,674	50,640
Colombia	6,652	22,046	55,116	77,162	82,673	88,945
Ecuador	497	348	601	416	388	228
Peru	96	662	514	386	324	364
Europe:						
Austria	313,668	356,150	379,076	370,809	385,088	405,781
Belgium	NA	44,476	NA	56,994	NA	NA
Bulgaria	[3] 38,581	61,729	60,627	67,241	84,878	[e] 85,900
Czechoslovakia	271,168	300,931	330,693	351,637	353,842	345,023
Denmark:						
Crude	6,363	6,950	8,567	[e] 8,800	[e] 8,300	8,818
Washed and pressed	5,609	5,405	4,669	3,644	NA	NA
France [4]	257,562	260,120	283,322	264,619	299,599	NA
Germany, West (marketable)	389,103	379,418	411,689	422,262	427,366	503,692
Greece	12,075	28,660	27,778	38,535	[e] 38,500	[e] 33,000
Hungary	20,878	47,939	46,697	44,994	48,760	[e] 50,000
Italy:						
Crude	65,655	70,586	94,968	81,375	86,817	70,273
Kaolinic earth	50,965	50,749	32,277	80,700	NA	NA
Portugal:						
Crude	25,587	19,836	21,951	14,082	41,871	13,472
Washed	28,057	31,825	32,810	33,857		28,738
Spain (crude)	91,544	123,860	139,875	184,960	228,849	NA
Sweden	5,407	29,464	29,873	28,911	35,053	NA
U.S.S.R.[e]	[5] 1,100,000	1,200,000	1,400,000	1,500,000	1,650,000	1,650,000
United Kingdom	1,363,778	1,834,244	1,924,663	1,640,000	[e] 2,130,000	[e] 2,280,000
Yugoslavia	[e] 16,500	[e] 11,200	[e] 7,800	5,000	4,500	5,500
Asia:						
Hong Kong	7,331	7,463	9,441	7,141	5,621	5,648
India	199,605	388,876	409,280	429,901	445,548	565,017
Indonesia (kaolin powder)	[6] 719	1,383	NA	NA	NA	NA
Iran [7]	[5] 518	4,740	3,307	NA	NA	NA
Japan	18,711	23,456	29,695	79,212	109,381	125,718
Korea, Republic of	20,840	56,472	56,523	42,101	57,609	66,729
Malaya	1,462	1,370	1,759	3,875	1,317	1,591
Pakistan	------	82	790	------	------	1,084
Taiwan	[6] 4,920	NA	NA	NA	NA	NA
Viet-Nam, South	3,072	1,874	NA	4,365	4,928	NA
Africa:						
Algeria	127	------	------	------	------	------
Eritrea	1,381	1,653	3,858	661	NA	NA
Kenya	1,318	1,161	817	1,294	7,345	1,415
Mozambique	117	127	132	198	6	11
Nigeria	75	4	------	6	17	NA
Rhodesia (formerly Southern)	------	6,614	20,386	------	12,240	21,000
South Africa, Republic of	17,269	29,202	26,474	31,366	37,413	43,495
Swaziland	------	------	58	2,743	2,212	344
Tanzania	64	246	171	175	201	122
United Arab Republic (Egypt)	7,330	24,729	29,961	16,095	26,503	69,221
Oceania: Australia [8]	45,629	53,979	57,219	40,399	56,794	NA

[e] Estimate. [p] Preliminary. NA Not available.

[1] China clay is also produced in Brazil, China, East Germany, Israel, Rumania, and Thailand, but data on production are not available; a negligible quantity is produced in Malagasy, Morocco, and Paraguay.

[2] Average annual production 1957–59.

[3] Average annual production 1958–59.

[4] Includes kaolinitic clay.

[5] Data for year 1959.

[6] Average annual production 1956–59.

[7] Year ended March 20 of year following that stated.

[8] Includes ball clay.

Canada.—Data on present and anticipated requirements of bentonite for iron ore pelletizing were published, together with information on Canadian sources of the material. Present iron ore pelletizing is dependent on imports of Wyoming swelling bentonite from the United States.[4]

Exploitation of large kaolin-silica deposits near Arborg, Manitoba, was under consideration, and research was under way to develop a commercial process for separation of the clay from the sand.[5]

Production of structural clay products increased about 6 percent in 1964.[6]

Ceylon.—A 5,500 ton kaolin processing plant in Ceylon was completed. Domestic industry was being expanded in order to use a substantial part of the production.[7]

Chile.—Reported production of clays other than kaolin totaled 18,831 short tons in 1964.

Hungary.—Prospecting of the high grade Hungarian kaolin deposits in the vicinity of Mad continued, and large scale mining and processing operations were planned. The strip mined area was to be restored and made suitable for production of grapes.[8]

India.—Fire clay production was 397,206 tons in 1964, down slightly from the 1963 output of 405,955 tons.

Israel.—A new $3.3 million clay preparation plant was under construction at Makhtesh Ramon. The new facility was to process refractory flint clay mined by Negev Ceramic Materials, Ltd. and Fine Sand Co. An Italian interest furnished nearly half of the investment.[9]

Italy.—Production of bentonite was 155,674 tons, down about 1 percent from that of 1963. Refractory clay production was 432,239 tons in 1964.

Japan.—Production of fire clay in 1964 was 1,007,740 tons.

Jordan.—Bentonite of commercial quality was discovered in the Jordan Valley by a German geological team.[10]

Mozambique.—Production of 917 tons of bentonite was reported in 1964.

New Zealand.—Nonswelling bentonite deposits in the Hunter Hills near Coalgate, Canterbury, were to be exploited by a new commercial scale plant which was expected to be in operation by the end of 1964.[11]

Peru.—Clay production was 288,561 tons in 1964, consisting of 364 tons of kaolin, 665 tons of bentonite, 9,702 tons of fire clay, and the balance common clay.

Poland.—A program for greater use of industrial minerals in Dolny Slask was in preparation. Among the possibilities for greater exploitation were kaolin deposits in Boleslawice Powiat and refractory shales at Nowa Ruda and Slupiec.[12]

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[4] Ross, J. S. Bentonite—A Challenge for Canadian Industry. Canadian Min. and Met. Bull., v. 57, No. 626, June 1964, pp. 648-652.

[5] Rock Products. V. 67, No. 8, August 1964, p. 114.

[6] Canada Department of Mines and Technical Surveys. Ottawa. The Canadian Mineral Industry in 1964. (Preliminary.) Miner. Inf. Bull., MR 79, February 1965, pp. 4-5.

[7] World Mining. V. 17, No. 3, March 1964. pp. 73-74.

[8] Figyelo (Budapest, Hungary) July 22, 1964, p. 10 (From East Europe Daily Press Report, Aug. 6, 1964).

[9] Bureau of Mines. Mineral Trade Notes. V. 59, No. 2, August 1964, p. 13.

[10] Bureau of Mines. Mineral Trade Notes. V. 58, No. 4, April 1964, p. 10.

[11] Chemical Age (London). V. 92, No 2354, Aug. 22, 1964, p. 274.

[12] Trybuna Ludu (Warsaw, Poland). Better Utilization of Mineral Deposits Urged. June 23, 1964, p. 5. (From East Europe Daily Press Report, July 8, 1964)

Rumania.—Long-term development plans were announced whereby Rumanian bentonite deposits were to be exploited on a larger scale by expansion of existing mines and opening of new ones.[13]

South Africa, Republic of.—Large deposits of kaolin were discovered near Johannesburg in the Transvaal and in the Bitterfontein area of Cape Province. A sample from the Cape Province deposit was sent to Japan for utilization tests.[14]

Premier Kiln Products (Pty.) Ltd., Johannesburg, completed a new flint clay calcining plant in Cullinan District, Transvaal. Production capacity was 4,000 to 5,000 long tons per month of calcined refractory clay containing about 40 percent alumina.[15]

Output of clay in South Africa in 1964 included 293,992 tons of fire clay, 10,267 tons of bentonite, and 180 tons of fuller's earth.

Southern Rhodesia.—Fire clay production was 15,134 tons, 4 percent higher than that in 1963.

Thailand.—A ceramic tile plant was approved on the basis of a suitable blend of clays from three regions. Costing nearly $500,000, the plant, equipped with Japanese machinery, was to be operating about the end of 1964.[16]

United Kingdom.—Historical and current data on the ball clay mines in South Devon were published. Open pit and underground mines presently operating in the area have been producing for at least 250 years.[17]

A new plant was completed by F. W. Berk & Co., Ltd., at Aspley, England, to produce 1,000 to 1,500 tons of minus 200 mesh bentonite per month for use primarily for foundry sand bond, drilling mud, and grouting.[18]

Fire clay production in Northern Ireland was 35,618 tons in 1964. Output of other clays was 359,650 tons.

Yugoslavia.—The only kaolin mine in Yugoslavia, at Crna, Slovenia, was to be expanded at cost of $2.4 million. Output was to be increased to 100,000 tons by 1970. Search was underway for new deposits to supply anticipated demand.[19]

TECHNOLOGY

A rapid X-ray method for quantitative determination of illite in clay and shale samples was developed. Measurement of half-peak widths and enhancement of basal reflections by slide sedimentation were not required with the new procedure. An accuracy of approximately ±6 percent of the illite present in five-component mixtures containing between 25 and 55 percent mica was claimed.[20]

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[13] Chemical Trade Journal and Chemical Engineering (London). V. 154, No. 4019, June 19, 1964, p. 894.

[14] E&MJ Metal and Mineral Markets. V. 35, No. 42, Oct. 19, 1964, p. 3.
World Mining. V. 17, No. 8, July 1964, p. 70.

[15] Holz, Peter. The Calcination of Flint Clay. Cement, Lime and Gravel. V. 39, No. 12, December 1964.

[16] Bureau of Mines. Mineral Trade Notes. V. 59, No. 3, September 1964, p. 10.

[17] Quarry Manager's Journal. Ball Clay Production in South Devon. V. 48, No. 8, August 1964, pp. 301–308.

[18] Mining and Minerals Engineering (London). V. 1, No. 4, December 1964, pp. 142–146.

[19] E&MJ. V. 165, No. 5, May 1964, p. 168.

[20] Lapham, Davis M., and Michael G. Jaron. Rapid, Quantitative Illite Determination in Polycomponent Mixtures. Am. Mineralogist, v. 49, Nos. 3–4, March-April 1964, pp. 272–276.

X-ray diffraction analysis of kaolinite and dickite was facilitated by application of two simple methods of reducing the preferential crystal orientation. Fine grinding of the samples reduced the orientation index but required use of nonbasal reflection and could be used only when no interfering lines were present. Larger material was used when basal reflection was necessary, requiring a special sample packing method and an end loading sample holder.[21]

Research continued on the factors that affect the mechanisms of flocculation, deflocculation, and other phenomena in kaolinite-water mixtures. In one investigation the addition of long molecules consisting of partially hydrolyzed polyacrylamide to a kaolin-water pulp, accompained by gentle mixing resulted in large, dense pellet-like flocs sufficiently strong to be wet screened.[22] New data were presented on the nature and location of electrostatic charges on the kaolinite platelets.[23]

An article describing an ultraflotation process included the flowsheet for a plant designed to produce extra high quality paper coating clay.[24]

Use of ionizing radiation to produce a cross-linked polymer direct-bonded to clay minerals was described. The new organosilicates were more resistant to heat and solvents than other polymers.[25]

Laboratory studies were made to determine if electrophoresis could compete economically with presently used methods such as sedimentation and centrifuging for recovery of fine clay from dilute slurries. New processing methods and equipment and decreasing electrical power costs indicate that consideration of electrical clay dewatering is warranted.[26]

Patents were obtained on use of kaolin in production of synthetic zeolites,[27] petroleum cracking catalysts,[28] and lightweight refractory aggregate for insulating refractories.[29]

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[21] Niskanen, Eric. Reduction of Orientation Effects in the Quantitative X-ray Diffraction Analysis of Clay Minerals. Am. Mineralogist, v. 49, Nos. 5–6, May-June 1964, pp. 705–714.

[22] Yusa, Mitsuo, and A. M. Gandin. Formation of Pellet-Like Flocs of Kaolinite by Polymer Chains. Am. Ceram. Soc. Bull., v. 43, No. 5, May 1964, pp. 402–406.

[23] Button, D. D., and W. G. Lawrence. Effect of Temperature on the Charge on Kaolinite Particles in Water. J. Am. Ceram. Soc., v. 47, No. 10, Oct. 21 1964, pp. 503–509.

Michaels, Alan S., and Justin C. Bolger. Particle Interactions in Aqueous Kaolinite Dispersions. Industrial and Engineering Chemistry Fundamentals, v. 3, No. 1, February 1964, pp. 14–20.

[24] Grounds, A. Fine-Particle Treatment by Ultraflotation. Mine & Quarry Eng. (London), v. 30, No. 3, March 1964, pp. 128–133.

[25] Chemical & Engineering News. New Class of Materials Formed by Bonding Clays to Polymers. V. 42, No. 43, Oct. 26, 1964, pp. 70–72.

[26] Kelly, Hal J., and Henry M. Harris. Electrical Dewatering of Dilute Clay Slurries. BuMines Rept. of Inv. 6479, 1964, 21 pp.

[27] Haden, W. L., Jr., and F. J. Dzieranowski (assigned to Minerals & Chemicals Philipp Corporation, Menlo Park, N.J.). Synthetic Crystalline Lithium Aluminum Silicate Zeolite and Method for Making Same. U.S. Pat. 3,123,441, March 3, 1964.

Howell, P. A., and A. Acara (assigned to Union Carbide Corp., New York, N.Y.). Process for Production Molecular Sieve Bodies. U.S. Pat. 3,119,660, Jan. 28, 1964.

Shuart, S. R., A. M. Gesaler and R. S. Hawley (assigned to Esso Research and Engineering Co., a corp. of Delaware). Processing Isoolefin-Diolefin Rubbery Copolymers with Kaolin Clays. U.S. Pat. 3,123,581, Mar. 3, 1964.

Taggart, Le R. I., and G. L. Ribaud (assigned to Union Carbide Corp., New York, N.Y.). Process for Producing Molecular Sieve Bodies. U.S. Pat. 3,119,659, Jan. 28, 1964.

[28] Bond, G. R., Jr. (assigned to Air Products and Chemicals Inc., a corp. of Delaware). Kaolin Cracking Catalysts Having Improved Oxidizing Characteristics. U.S. Pat. 3,153,635, Oct. 20, 1964.

Stover, W. A., and W. S. Briggs (assigned to W. R. Grace & Co., New York, N.Y.). Preparation of Cracking Catalysts from Clay. U.S. Pat. 3,130,170, Apr. 21, 1964.

[29] Bundy, W. M. (assigned to Georgia Kaolin Co., Elizabeth, N.J.). Planographic Inks Containing Aluminum Hydroxide Coated Kaolinite Particles. U.S. Pat. 3,131,062, Sept. 29, 1964.

A comprehensive report was completed giving the results of a Bureau of Mines study of the locations and potential usefulness of refractory and buff burning clays in Utah. Information on nearly 100 deposits and occurrences is included.[30]

The cost of blasting flint and plastic fire clays in some Missouri open pits, which had increased to about 4 cents per ton in 1960 using straight dynamite, was reduced to less than 2 cents per ton within a 2-year period by use of ammonium nitrate-fuel oil mixtures detonated by dynamite. Several advantages other than cost were cited, including availability, simplified storage, and safety.[31]

The effects of clay temperature and ambient temperature on the modulus of rupture of green fire clay brick were studied. Clay temperature affected the modulus of rupture, with brick formed from 28° F clay having the lower value. Low ambient temperatures had little effect if the brick were subsequently dried at about 72° F, so long as freezing did not occur during the curing period. Brick loss from structural weakness in the green state could be lowered by using clays at 72° F and by preventing the brick from freezing prior to firing.[32] Recent studies indicated that moisture lowered the modulus of rupture of fire brick, and oven drying of brick prior to testing for this property was suggested.[33]

New data were presented on the starting materials, temperature, hydrogen ion activity, and other requirements for synthesis of kaolin minerals at low temperatures.[34]

A pilot plant was established to continue work on production of a synthetic clay similar to hectorite. The synthetic clay was highly thixotropic and was expected to be useful in many products and applications.[35]

The mechanisms of casting defects from expansion due to the influence of improper proportions of water and bentonite in foundry sands were described, and criteria were presented for use in eliminating or minimizing the expansion defects.[36]

The results of similar studies on the effects of the percentages of clay and water on hot strength and dry strength of molding sand were also published.[37]

Pneumatic transportation of bentonite throughout a modern iron ore pelletizing plant was described. Special equipment was required to prevent the finely ground bentonite from escaping, absorbing moisture, and forming slick unsafe working conditions on floors and other plant surfaces.[38] Use of lignite (leonardite) and caustic soda as the binder in experimental production of iron ore pellets from taconite and hematite concentrates resulted in satisfactory pellets with a lower percentage of impurities than pellets made with bentonite binder. Satisfactory results were not obtained with synthetic magnetite.[39]

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[30] Van Sant, Joel N. Refractory-Clay Deposits of Utah. BuMines Inf. Circ. 8213, 1964, 176 pp.

[31] Dunlop, Mitchell S. Blasting plastic and flint clays with ammonium nitrate. Brick & Clay Record, v. 144, No. 6, June 1964, pp. 60–61, 81.

[32] Eberle, Charles D. Clay Temperature Versus Kiln Loss. Ceram. Age, v. 80, No. 9, September 1964 pp. 36–37.

[33] Smothers, W. J., J. R. Kreglo, Jr., and E. Moscker. Effect of Moisture on Strength of Refractory Brick. J. Am. Ceram. Soc., v. 47, No. 8, August 1964, pp. 414–415.

[34] De Kimpe, C., M. C. Gastuche, and G. W. Brindley. Low-Temperature Synthesis of Koalin Minerals. Am. Mineralogist, v. 49, Nos. 1–2, January–February 1964, pp. 1–16.

[35] Chemical Age (London). Laporte Produce New Synthetic Clay. V. 92, No. 2367, Nov. 21, 1964, p. 773.

European Chemical News (London). V. 6, No. 149, Nov. 20, 1964, p. 44.

[36] Yearley, B. C. Influence of Clay and Water on Expansion Defects. Foundry, Pt. 1, v. 92, No. 11, November 1964, pp. 73–77. Pt. 2, v. 92, No. 12, December 1964, pp. 49–53.

[37] Yearley, B. C., and J. D. Hedberg. How Clay and Water Affect Hot Strength. Foundry, v. 92, No. 6, June 1964, pp. 76–79.

———. How Clay and Water Affect Dry Strength. Foundry, v. 92, No. 7, July 1964, pp. 60–62.

[38] Iron Age. Bentonite Travels in Air Stream. V. 194, No. 7, Aug. 13, 1964, pp. 80–81.

Bentonite was used in conjunction with the drilling and cutting of a 1,400-foot trench, 175 feet deep and 2½ feet wide at the Allegheny Dam in northwestern Pennsylvania. The bentonite, mixed with water to form a slurry, sealed and held the trench wall until cement could be poured to form a water barrier to protect the earthfill section of the dam. The barrier, which was drilled, excavated, and poured in sections, required about 1,000 tons of bentonite.[40]

Swelling bentonite, mixed with lime, diatomite and kaolin was used in a patented temperature control spray for protection of fruit and plants.[41] A patented process for clarifying turbid water consisted of the addition of hectorite or Wyoming bentonite and an acrylamide polymer which formed settleable flocs with the material causing the turbidity.[42] Two patents were issued on the use of hectorite in the processing of fermented beer to improve the clarity of the product. In one case dry natural hectorite was used, and in the other a vinyl pyridine modified hectorite was required.[43]

Processes were patented which included the use of bentonite in shaped ceramic nuclear fuels [44] and radiation resistant ceramic moderators.[45]

A British patent for removal of oils from sea or inland waters included the use of bentonite, a halogenated hydrocarbon, and barite or portland cement.[46]

A mastic coating composition based on synthetic rubbers and a petroleum fraction condensation product included the use of an organic derivative of bentonite as a gelling agent.[47]

Patents were issued for use of attapulgite in phosphoric acid and ammonia-base fertilizers,[48] nonflocculated thixotropic pesticides,[49] molecular sieve sorbents,[50] and a briquette containing glass furnish ingredients.[51]

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[39] Fine, M. M., and W. C. Wahl. Iron Ore Pellet Binders from Lignite Deposits. BuMines Rept. of Inv. 6564, 1964, 18 pp.

[40] Monaghan, John O. Slurry Drilling Method Sinks Deep Trench. Construction Methods and Equipment, v. 46, No. 9, September 1964, pp. 106–111.

[41] Aluisi, D., and J. R. Aluisi. Agricultural Spray. U.S. Pat. 3,120,445, Feb. 4, 1964.

[42] Pye, D. J. (assigned to The Dow Chemical Co., Midland, Mich.). Method for Clarifying Water. U.S. Pat. 3,128,249, Apr. 7, 1964.

[43] Goerl, G. F. (assigned to American Tansul Co., San Francisco, Calif.). Addition of Dry Clay to Beer. U.S. Pat. 3,145,106, Aug. 18, 1964.

McAdam, R. L., R. G. Shaler, Jr., and R. G. Shaler (assigned to American Tansul Co., San Francisco, Calif.). Beer Production With Amine Modified Clays. U.S. Pat. 3,163,537, Dec. 29, 1964.

[44] O'Leary, W. J., and E. A. Fisher (assigned to U.S. Atomic Energy Commission). Process of Making Shaped Fuel for Nuclear Reactors. U.S. Pat. 3,121,128, Feb. 11, 1964.

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[46] Grunwald, G. F., and E. Arnt (assigned to H. B. D. Borgwaldt). British Pat. 954,797, Apr. 8, 1964.

[47] Steltz, Irving J., and Grey F. Rolland (assigned to Benjamin Foster Co., Philadelphia, Pa., a corp. of Delaware). Mastic Coating Composition. U.S. Pat. 3,147,266, Sept. 1, 1964.

[48] Smith, H. A., and E. W. Sawyer, Jr. (assigned to Minerals and Chemicals Philipp Corp., Menlo Park, N.J.). Wet Process Phosphoric Acid and Liquid Fertilizer Compositions Containing the Same. U.S. Pat. 3,160,495, Dec. 8, 1964.

Smith, H. A., and E. W. Sawyer, Jr. (assigned to Minerals and Chemicals Philipp Corp., Menlo Park, N.J.). Conditioned Ammonia Derivative Composition. U.S. Pat. 3,125,434, Mar. 17, 1964.

[49] Harrison, T. S., and C. A. Littler (assigned to E. I. du Pont de Nemours & Co., Inc., Wilmington, Del.). Pesticidal Dispersion and Method for Preparing the Same. U.S. Pat. 3,157,486, Nov. 17, 1964.

[50] Pollitzer, E. B., and B. Kvetinskas (assigned to Universal Oil Products Co., Des Plaines, Ill.). Molecular Sieve Sorbents Bonded with an Ion-Exchanged Clay. U.S. Pat. 3,158,579, Nov. 24, 1964.

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A method described for converting cull brick to premium products included application of cold coatings [52] and the use of engobes or fired coatings.[53] The increased value of the coated brick more than offset the costs of coating. Data were published indicating that automated production of molded brick can be accomplished at a cost approaching that of extruded brick and offers several advantages such as elimination of predrying of clays, low power requirements, product versatility, and the fact that some clays can be molded but not extruded.[54] Isostatic pressing of heavy clay products as large as 30 inches in diameter was described. Previously the process has been used only for such items as high cost ceramics, super refractories, and nuclear materials.[55]

Monolithic "Y" and "T" fittings for sewer pipe were made on a production line basis by a new process. In addition to the savings in production time, the new fittings were more uniform and stronger than those molded and attached by hand.[56] Tight gasket joints in clay pipe were made with foamed epoxy resins by use of a patented device.[57]

Laminations in extruded clay columns were greatly reduced by compression between two or more pairs of rollers prior to being cut into brick.[58]

The cause of defects resulting from humidity drying of plastic clay bodies was investigated. Condensation of moisture on the surface of the bodies appeared to be the major cause of cracking.[59] Reactive hot-pressing, consisting of application of pressure to clay bodies during phase transformations, resulted in greatly increased compressive strength compared to clay bodies fired at normal pressure prior to pressing.[60]

Fast firing of ceramic wall tile using one-high stacking and firing cycles of 2 hours or less became closer to commercial realization as the result of additional research using high-wollastonite and high-talc ceramic bodies. Comparative costs for conventional and fast firing processes were presented.[61]

In a patented British process for production of brick, coal mine waste shales were treated to remove combustible material, after which the shale was processed into brick, which were fired with the combustibles previously removed.[62] In contrast, an Indian patent was issued on a process which required the incorporation of coal mine waste or other low grade fuel into clay brick in sufficient quantity to provide from 40 to 80 percent of the fuel required for firing.[63]

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[52] Brick & Clay Record. How to Apply Cold Coatings on Brick. V. 145, No. 3, Sept. 1964, pp. 60–61.

[53] Thomas, David. The Economics of Engobe on Brick. Brick & Clay Record, v. 144, No. 4, April 1964, pp. 75–79, 107–108.

[54] Pixley, George W. Automated Molded Brick Production. Ceramic Age, v. 80, No. 12, December 1964, pp. 32–34.

[55] Svec, J. J. Heavy Clay Products and Shapes Fabricated in One Step. Brick & Clay Record, v. 145, No. 6, December 1964, pp. 45, 56–57.

[56] Mohler, Neal. A Technological Breakthrough in Clay Forming. Brick & Clay Record, v. 145, No. 1, July 1964, pp. 37–39.

[57] Ligon, E. R., and G. E Pitzer (assigned to W. S. Dickey Clay Mfg. Co., Kansas City, Mo.). Casketed Joints for Ceramic Pipe and Method and Apparatus for Forming Same. U.S. Pat 3,135,519, June 2, 1964.

[58] Astbury, N. F., and H. R. Hodgkinson (assigned to the British Ceramic Research Association). British Pat. 970, 661, Sept 23, 1964, 5 pp.

[59] Lancaster, Bryan W., and Eric R. McCartney. Humidity Drying of Plastic Clay. J. Am. Ceram. Soc., v. 47, No. 6, June 1964, pp. 291–296.

[60] Chaklader, A. C. D., and L. G. McKenzie. Reactive Hot-Pressing of Clays. Am. Ceram. Soc. Bull., v. 43, No. 12, December 1964, pp. 892–893.

[61] Ceramic Age. Fast Firing: Still More Questions Than Answers. V. 80, No. 4, April 1964, pp. 28–31.

[62] Musson, C. (assigned to Bryncethin Brickworks Ltd.). British Pat. 971,863, Oct. 7, 1964.

An automatic device to control cooling of ceramic ware in the kiln and prevent cracking during the time it passes through the beta-alpha inversion point was patented.[64]

The second report on Federal-State cooperative sampling and evaluating clays and shales in Virginia was published by the Virginia Division of Mineral Resources. Over 150 samples from 14 west-central Virginia counties were tested for ceramic and other uses.[65] Test drilling by the Kansas Geological Survey resulted in reserve estimates totaling 10 million tons of buff-burning clays suitable for making brick and other clay products.[66]

Data were published by the Bureau of Mines and State agencies on expandable clays and shales in Alabama,[67] Connecticut,[68] Indiana,[69] and Iowa.[70] A comprehensive study of the clay and shale lightweight aggregates industry in the South Central States released by the Bureau of Mines included information on plant locations, production methods, raw materials used, marketing areas, and transportation and other costs. Capital investment, operating costs, and other data for a hypothetical 500 yard-per-day plant were included.[71]

Bureau of Mines research resulted in improved methods for production of sintered lightweight aggregates from coal washery wastes. Two plants in West Virginia supplied the raw material and cooperated in the study.[72]

Data on capital investment, operating costs, and profit potential for a hypothetical 1,000-ton-per-day expanded clay or shale plant were published. Under the conditions stipulated, including an estimated selling price of $6.50 per ton, the break-even point occurred when production was at 35 percent of maximum capacity, and, using a conservative estimate of probable sales, the average profit over the estimated life of 20 years was 14 percent.[73]

A 125-yard-per-day lightweight clay aggregate plant producing super-light material by a new process was described. Clay, 50 mesh, mixed with wheat flour was pelletized, preheated, and expanded by dropping through the 20-foot-long bloating section of the furnace which was heated to about 3,000° F. Plant costs and manpower and fuel requirements were given. European aggregates producers have shown interest in the material and process, which was patented in the United States.[74]

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[63] Nikex Nehezipari Kulkereskedelmi Vallalat. Indian Pat. 75,696, Nov. 12, 1962.

[64] Cross, O. H. (assigned to Pullman Inc., Pittsburgh, Pa.). Method and Apparatus for Controlling the Cooling Zone of a Tunnel Kiln. U.S. Pat. 3,142,884, Aug. 4, 1964.

[65] Carver, James L., C. E. Smith, and D.C. Levan, in Cooperation with the U.S. Department of the Interior, Bureau of Mines, Analyses of Clay, Shale and Related Minerals—West Central Counties. Commonwealth of Virginia, Department of Conservation and Economic Development, Division of Mineral Resources, Mineral Resources Report 5, 1964, 230 pp.

[66] Mining Congress Journal. V. 50, No. 6, June 1964, p. 107.

[67] Pallister, Hugh D., Earl L. Hastings, and Thomas W. Daniel, Jr. Clay and Shale for Lightweight Aggregate in Alabama. Ala. Circ. 26, 1964, 45 pp.

[68] Millar, W. T., and H. P. Hamlin. Examining and Testing Clay From Hartford County, Conn., for Lightweight Aggregate Use. BuMines Inf. Circ. 8228, 1964, 21 pp.

[69] Rooney, Lawrence F., and Jack A. Sunderman. Lightweight Aggregate Potential in Northern Indiana. Brick & Clay Record, v. 144, No. 4, April 1964, pp. 98–99 and 116.

[70] Sweeney, John W., and Howard P. Hamlin. Lightweight Aggregates: Expansion Properties of Selected Iowa Shales, Clays, and Loess. BuMines Rept. of Inv. 6393, 1964, 33 pp.

[71] Diamond, W. G., Thomas R. Early, and Harry F. Robertson. Expanded Clay and Shale Lightweight Aggregate Industry in the South-Central United States. BuMines Inf. Circ. 8233, 1964, 50 pp.

[72] Myers, J. W., J. J. Pfeiffer, and A. A. Orning. Production of Lightweight Aggregate From Washery Refuse. BuMines Rept. of Inv. 6449, 1964, 19 pp.

[73] Harwell, R. Sterling. Planning for Profits in Lightweight Aggregate Production. Brick & Clay Record, v. 145, No. 2, August 1964, pp. 28–31, 50, 52–53, 56.

Criteria important to location and utilization of expandable clays, shales, and slates were published. Market potential, mining methods, and availability of fuels were listed as important factors which must be considered regardless of the bloatability of the raw materials. The effects of grain size and nonclay minerals on suitability of clays were cited.[75]

Patents were issued on lightweight aggregate production methods involving fluidized bed suspension of the aggregates in the expansion furnace.[76]

In another patented process, lightweight clay or shale aggregates are compressed into molds while still in the pyroplastic condition to form lightweight structural elements.[77] Processes involving surface additives designed to accelerate bloating and prevent sticking of aggregates in expansion furnaces were patented.[78] In a Soviet patent, the continuous addition of water in the firing zone increased bloating and lowered fuel requirements.[79]

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[74] American Ceramic Society Bulletin. SCR Veri-Lite Promises. V. 43. No. 5, May 1964, pp. 408–409.

Mohler, Neal F. New Concept in clay products now a reality. Brick & Clay Record, v. 144, No. 5, May 1964, pp. 36–39.

Parsons, Joseph R. (assigned to Chicago Fire Brick Company, Chicago, Ill., a corp. of Illinois). Lightweight Refractory Aggregate and Process for Making Same. U.S. Pat. 3,150,989, Apr. 23, 1964.

Svec, J. J. B&CR Industry Report From Europe. Brick & Clay Record, v. 145, No. 6, December 1964, pp. 30–31.

[75] Mining Engineering. Prospecting for Expansible Shale. V. 16, No. 1, January 1964, pp. 50–51.

[76] Dennert, H. (assigned to Veit Dennert, K. G., Schlusselfeld, (West Germany). Apparatus for Manufacturing a Porous Material Such as Blown Clay, By Heating. U.S. Pat. 3,118,658, Jan. 21, 1964.

Dennert, H., and M. Dennert. British Pat. 960,902, June 17, 1964, 4 pp.

[77] Veit Dennert K. G., Baustoffbetriebe (assignee). British Pat. 969,678, Sept. 16, 1964, 2 pp.

[78] Tacken, J. German Pat. 1,160,776, Jan. 2, 1964, 2 pp.

———. French Pat. 1,340,692, Sept. 9, 1963, 3 pp.

[79] Gervido, I. A. U.S.S.R. Pat. 153,435, date unknown, 1 pp.

Cobalt

By Harold W. Lynde, Jr.[1]

◆

WORLD PRODUCTION of cobalt rose 12 percent. The Republic of the Congo (Léopoldville) maintained its position as the leading producer, supplying 60 percent of the total. The only domestic cobalt ore was produced by Bethlehem Cornwall Corp., Pa.

Domestic consumption was about equal to that of the previous year, but with some change in the pattern of reported usage. Cobalt consumption for cutting and wear resisting materials, alloy hard-facing rods and materials, and nonferrous alloys increased considerably.

Legislation and Government Programs.—No cobalt exploration projects were active in 1964 under the program administered by the Office of Minerals Exploration.

As a result of supply-requirements studies, the national (strategic) stockpile objective for cobalt was increased from 19 million pounds to 42 million pounds. Government inventories included 96.0 million pounds of specification-grade cobalt, with 76.1 million pounds in the national (strategic) stockpile, 18.9 million pounds in the Defense Production Act (DPA) inventory, and 1.1 million pounds in the supplemental stockpile. Of the total, 54.0 million pounds was declared surplus. An additional 6.2 million pounds of cobalt in the DPA inventory did not meet stockpile specifications.

During 1964 5,420 pounds of cobalt was sold from inventory.

DOMESTIC PRODUCTION

Bethlehem Cornwall Corp., the only producer of colbalt concentrate, increased production 20 percent. A cobaltous pyrite concentrate was recovered from magnetite ores mined at Cornwall and Morgantown, Pa. The pyrite concentrate was calcined and leached by the company at Sparrows Point, Md. The resulting sulfate solution was shipped to Pyrites Co., Inc., Wilmington, Del., for recovery of cobalt.

The Bunker Hill Co., at its Kellogg, Idaho, zinc plant, recovered 138 tons of residue containing about 7,176 pounds of cobalt. Shipments of residues were 1,618 tons containing about 62,131 pounds of cobalt.

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[1] Commodity specialist, Division of Minerals.

TABLE 1.—Salient cobalt statistics

(Thousand pounds of contained cobalt)

	1955–59 (average)	1960	1961	1962	1963	1964
United States:						
Consumption	9,180	8,930	9,596	11,268	10,529	10,650
Imports for consumption	17,616	12,170	10,495	12,433	10,522	12,443
Stocks, Dec. 31: Consumer	1,159	1,856	1,807	1,479	1,099	1,420
Price: Metal per pound	$2.60–$1.75	$1.75–$1.50	$1.50	$1.50	$1.50	$1.50
World: Production	31,000	31,400	29,600	31,800	25,800	29,000

TABLE 2.—Cobalt materials consumed by refiners or processors in the United States

(Thousand pounds of contained cobalt)

Form [1]	1955–59 (average)	1960	1961	1962	1963	1964
Alloy and concentrate	5,012	2,062	1,121	721	1,075	1,174
Metal	948	961	1,101	1,255	1,339	1,392
Hydrate	67	18	16	17	15	21
Other	177	30	33	52	6	9

[1] Total consumption is not shown because some metal, hydrate, and carbonate was derived from alloy and concentrate.

TABLE 3.—Cobalt products [1] produced and shipped by refiners and processors in the United States

(Thousand pounds)

Product	1963				1964			
	Production		Shipments		Production		Shipments	
	Gross weight	Cobalt content	Gross weight	Cobalt content	Gross weight	Cobalt content	Gross weight	Cobalt content
Oxide	424	297	419	294	430	302	434	305
Hydrate	445	216	389	195	705	271	654	256
Salts:								
Acetate	229	54	236	56	410	97	370	88
Carbonate	472	216	419	195	523	231	458	201
Sulfate	589	132	565	126	548	120	464	102
Other	304	73	317	73	257	58	211	48
Driers	9,165	572	8,886	553	10,193	650	9,529	594
Total	11,628	1,560	11,231	1,492	13,066	1,729	12,120	1,594

[1] Figures on metal withheld to avoid disclosing individual company confidential data.

TABLE 4.—Cobalt consumed in the United States, by uses

(Thousand pounds of contained cobalt)

Use	1955-59 (average)	1960	1961	1962	1963	1964
Metallic:						
High-speed steel	201	155	220	343	404	305
Other tool steel	221	53	44	64	138	154
Other alloy steel		574	540	546	697	563
Permanent magnet alloys	2,770	2,387	2,457	2,867	2,352	2,210
Cutting and wear-resisting materials	206	263	257	316	275	337
High-temperature, high-strength alloys	2,722	2,024	2,354	3,015	2,453	2,461
Alloy hard-facing rods and materials	485	447	550	650	607	801
Cemented carbides	259	320	298	610	409	431
Nonferrous alloys	360	107	145	128	158	326
Other		495	659	582	426	427
Total	7,224	6,825	7,524	9,121	7,919	8,015
Nonmetallic (exclusive of salts and driers):						
Ground-coat frit	513	465	526	533	580	599
Pigments	225	190	192	168	222	209
Other	167	278	314	474	606	548
Total	905	933	1,032	1,175	1,408	1,356
Salts and driers: Lacquers, varnishes, paints, inks, pigments, enamels, glazes, feed, electroplating, etc. (estimate)	1,051	1,172	1,040	972	1,202	1,279
Grand total	9,180	8,930	9,596	11,268	10,529	10,650

TABLE 5.—Cobalt consumed in the United States, by forms

(Thousand pounds of contained cobalt)

Form	1955-59 (average)	1960	1961	1962	1963	1964
Metal	6,922	6,761	7,478	9,091	8,146	8,265
Oxide	830	757	900	998	935	958
Purchased scrap	377	240	178	207	246	148
Salts and driers	1,051	1,172	1,040	972	1,202	1,279
Total	[1] 9,180	8,930	9,596	11,268	10,529	10,650

[1] Includes a small quantity of ore and alloy.

PRICES

Prices remained unchanged from 1963. The price of cobalt metal (99+ percent cobalt) shot was $1.50 per pound, f.o.b. carrier, New York, or Chicago, Ill., in 500-pound kegs. Fines (95 to 96 percent cobalt) were $1.50 per pound contained cobalt, f.o.b. carrier, New York. Ceramic-grade oxide in 250-pound containers delivered east of the Mississippi River was $1.12 per pound (70 to 71 percent cobalt) and $1.15 (72½ to 73½ percent cobalt); oxide prices were 3 cents higher west of the Mississippi River. Metallurgical grade cobalt oxide (75 to 76 percent cobalt) was $1.65 per pound contained cobalt, in 250-pound kegs, f.o.b. carrier, New York.

FOREIGN TRADE

Exports of cobalt-bearing materials decreased 32 percent from 1963 to 1,453,000 pounds gross weight, including 1,283,000 pounds of ores, concentrates, metals, and alloys in crude form, and scrap valued at $1 million, and 170,000 pounds of semifabricated forms, valued at $1 million. Of the total value, Japan received 34 percent; Canada, 22 percent; Federal Republic of Germany, 12 percent; Australia, 9 percent; France, 6 percent; Italy, 5 percent; and the United Kingdom, 4 percent.

There were no changes in tariff schedules during 1964.

TABLE 6.—U.S. imports for consumption of cobalt, by classes

(Thousand pounds and thousand dollars)

Year	Metal		Oxide		Salts and compounds		Total [1]	
	Gross weight	Value	Gross weight	Value	Gross weight	Value	Gross weight	Cobalt content (estimated)
1955-59 (average)	[2] 15,862	[2] $33,703	988	$1,405	327	$191	19,823	17,616
1960	10,801	17,093	1,459	1,520	230	104	18,952	12,170
1961	10,036	14,867	681	663	159	59	10,876	10,495
1962	11,809	17,119	978	943	120	47	12,907	12,433
1963	10,322	14,677	468	451	94	45	10,913	10,522
1964	11,333	16,526	1,514	1,422	94	43	12,941	12,443

[1] Includes imports of white alloy (1955–59) and ores and concentrates, (1955–59, 1960, 1962, and 1963).
[2] Includes scrap.

Source: Bureau of the Census.

TABLE 7.—U.S. imports for consumption of cobalt metal and oxide, by countries

(Thousand pounds)

Country	Metal		Oxide (gross weight)	
	1963	1964	1963	1964
Belgium-Luxembourg	1,419	1,744	460	1,449
Canada	630	660	8	54
Congo (Léopoldville)	4,846	5,246	----	----
France	763	971	----	----
Germany, West	1,351	1,401	----	----
Japan	52	36	----	----
Netherlands	52	28	----	----
Norway	1,056	1,222	----	----
United Kingdom	153	25	----	11
Total	10,322	11,333	468	1,514

Source: Bureau of the Census.

WORLD REVIEW

Canada.—The International Nickel Company of Canada, Ltd. (Inco), recovered electrolytic cobalt at its Port Colborne, Ontario refinery, and also an impure cobalt oxide sinter which was shipped to Clydach, Wales, for processing into cobalt salts and oxides. Cobalt oxide was produced at its Thompson, Manitoba, refinery. The company delivered 2,750,000 pounds of contained cobalt in 1964, compared with 2,150,000 pounds in 1963.[2]

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[2] The International Nickel Company of Canada, Ltd. Annual Report. 1964, 39 pp.

TABLE 8.—World production of cobalt by countries[1] [2]

(Short tons of contained cobalt)

Country[1]	1955-59 (average)	1960	1961	1962	1963	1964[p]
Australia (recoverable cobalt in zinc concentrate)	14	14	14	18	19	[e] 11
Canada[3]	1,662	1,784	1,591	1,741	1,512	1,598
Congo, Republic of the (Leopoldville) (recoverable cobalt)	8,974	9,063	9,178	10,674	8,131	8,700
Cuba (recoverable cobalt from sulfide slurry)[e]	[4] 99	68	----------	181	192	NA
Morocco (content of concentrate)	880	1,401	1,422	1,583	1,511	1,850
New Caledonia (content of concentrate)	[5] 68	----------	----------	----------	----------	----------
United States (recoverable cobalt)	1,406	(6)	(6)	(6)	(6)	(6)
Zambia (formerly Northern Rhodesia) (content of white alloy, cathode metal and other products)	1,518	2,036	1,701	951	778	1,552
World total[e] [1] [2]	15,500	15,700	14,800	15,900	12,900	14,500

[e] Estimate. [p] Preliminary. NA Not available.

[1] Cobalt is also recovered, principally in West Germany, from pyrites produced in Finland, and estimates are included in the world total. Production data for Bulgaria, East Germany, Poland, and U.S.S.R. are not available, and no estimates for these countries are included in the world total. Cobalt concentrates are being stockpiled in Uganda, but exact figures are not available.

[2] This table incorporates some revisions. Data do not add exactly to totals shown because of rounding where estimated figures are included in the detail.

[3] Cobalt in all forms. Excludes the cobalt content of nickel-oxide sinter shipped to the United Kingdom by International Nickel Company of Canada Ltd., but includes the cobalt content of Falconbridge Nickel Mines Ltd. shipments of nickel-copper matte to Norway.

[4] One year only, as 1959 was the first year of commercial production.

[5] Average annual production 1958-59.

[6] Included with world total to avoid disclosing individual company confidential data.

Falconbridge Nickel Mines Ltd., reported increased deliveries of cobalt. The company delivered 1,262,000 pounds in 1963. The cobalt was recovered from Sudbury nickel-cobalt matte exported to the Falconbridge Nikkelverk, A/S, refinery at Kristiansand South, Norway.[3]

Sherritt Gordon Mines Ltd., produced cobalt metal in powder, briquets, and strip at its Fort Saskatchewan, Alberta, refinery. The cobalt was recovered from the company's Lynn Lake, Manitoba, nickel-copper ores. Production in 1964 was 594,249 pounds, and sales were 621,535 pounds.[4]

Cobalt Refinery Ltd., a subsidiary of Violamac Mines Ltd., produced cobalt and nickel oxide. The company reported that it processed ores of all but one producer in the Cobalt-Gowganda area, Ontario.[5]

Eldorado Mining & Refining Ltd., announced development of a process to recover cobalt from uranium-process tailings or from silver-cobalt concentrates. Eldorado was to begin commercial operations at Port Hope, Ontario, in 1965 to recover and purify cobalt, nickel, and arsenic from Cobalt-Gowganda ore concentrates; silver recovery and purification were to continue at Cobalt Refinery. Each planned to process the other's byproduct.[6]

Congo, Republic of the (Léopoldville).—Union Minière du Haut-Katanga increased production about 7 percent to 8,531 tons of cobalt metal and 174 tons of contained cobalt in alloy. Operations were hampered by continuing political unrest, transportation difficulties, and a shortage of technical personnel.

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[3] Falconbridge Nickel Mines Ltd. Annual Report. 1964, 33 pp.

[4] Sherritt Gordon Mines Ltd. Annual Report. 1964, 16 pp.

[5] Violamac Mines Ltd. Annual Report. 1964, 16 pp.

[6] Schneider, V. B. Additive, Refractory and Reactive Metals. Cobalt. The Canadian Mineral Industry in 1964, Preliminary. Dept. Mines and Tech. Surveys, Ottawa, Canada, Miner. Inf. Bull. MR 79, 1965, p. 42.

Morocco.—Société Minière de Bou-Azzer et du Graara produced 16,813 tons of concentrate averaging about 11 percent cobalt. Exports were about 16,000 tons, all to France and Federal Republic of Germany. Production increased 11 percent over 1963, and exports declined 12 percent; stocks of concentrate on hand increased to 4,352 tons.

Zambia.—Chibuluma Mines Ltd., subsidiary of Roan Selection Trust Ltd. (formerly Rhodesian Selection Trust Ltd.) closed its cobalt plant at Ndola in February because it was not profitable. The plant had been in operation since 1957, producing a cobalt-copper-iron matte which was exported to Belgium. The cobalt-copper concentrate from the Chibuluma concentrator was stockpiled, and may eventually be treated in the metallurgical plant of the new Chambishi mine which was scheduled to begin production in 1965.[7]

The Rhokana Corporation Ltd. cobalt plant at Nkana was shut down from April to October for a major overhaul. Despite the closures, reported production was about double that of 1963.

TECHNOLOGY

Developments in cobalt research and technology during the preceding 6 years were discussed and summarized at an international meeting held in Brussels, Belgium.[8] New techniques for preparation of very high purity cobalt and for study of its physical properties have resulted in much improved basic data. Advances in magnetic materials including use of trace elements, development of columnar crystallized magnets, and electrodeposition of cobalt alloy, have resulted from systematic determination of phase diagrams, study of heat treatment, and the development of electrolytic and electroless deposition. Higher quality and more uniform heat-resisting alloys are produced by vacuum melting. Some of the newly developed heat-resisting alloys contain nonmetallic dispersions. There is increased use of cobalt in high-strength steels and in stainless steels. Cobalt also finds more use in lightweight, high-strength alloys.

A monograph was published dealing primarily with the cobalt ore deposits of the world, and also including sections on mineralogy, mining and recovery, preparation, properties, production, and marketing.[9]

An improved geochemical field method for the determination of cold extractable cobalt in soils and sediments was described.[10]

Several articles dealing with recovery or extraction of cobalt were published. The Bethlehem Steel Co. plant at Sparrows Point, Md., which went on stream in March 1963, leaches cobalt from roasted pyrite concentrate.[11] In Canada, Eldorado Mining Refining Ltd. has developed a process to recover cobalt from cobalt-silver ore concentrates and from uranium processing tailings.[12] An electrochemical method for recovery of a cobalt-nickel alloy from superalloy scrap was described.[13] The process achieved about 80 percent recovery of the cobalt and nickel.

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[7] Rhodesian Selection Trust Ltd. Annual Report. 1964, 32 pp.

[8] Cobalt. Journées Internationales Des Applications Du Cobalt. No. 24, September 1964, pp. 115–124.

[9] Andrews, R. W. Cobalt. Overseas Geological Surveys, Mineral Resources Division. Her Majesty's Stationery Office, London, 1962, 222 pp.

[10] Canney, F. C., and G. A. Nowlan. Determination of Ammonium Citrate-Soluble Cobalt in Soils and Sediments. Econ. Geol., v. 59, No. 7, November 1964, pp. 1361–1367.

Sherritt Gordon Mines Ltd. produced a high-purity (99.92 percent) ductile cobalt strip by compaction of cobalt powder.[14] The combination of high purity and ductility permits many uses: Chemical standard, anode material, other electrolytic applications, complex shapes, high temperature magnetic uses, inhomogeneous welding rods, wear-resistant material, and new catalytic uses. Another article stated that lack of ductility in cast cobalt is due primarily to presence of sulfur, lead, and zinc, and showed that oxidizing refining followed by vacuum degassing and annealing would produce a ductile metal.[15]

There was continuing research emphasis to improve the special high-temperature, high-strength properties of existing cobalt-bearing alloys and to develop entirely new alloys.

Among the alloys described were UMCo–51, a high-temperature, corrosion-, oxidation-, and thermal shock-resistant cobalt-base alloy with improved stress rupture resistance compared with UMCo–50;[16] Co–W superalloys with titanium, zirconium, chromium, and rhenium which have low evaporative loss rates, for areospace use;[17] Haynes No. 150, a cobalt-base alloy for high temperature heat-treating service, with a high melting range and resistance to thermal shock, air oxidation, and air-sulfur dioxide mixtures;[18] and MAR–M–302 and M–322, cobalt-base alloys with strength as cast to very high temperatures.[19]

A summary of current use of cobalt tool steels also described research and trends.[20] European research developments were stressed.

Several permanent magnet alloys were described. Two platinum-cobalt alloys have superior magnetic properties, with high flux in small sizes. In addition, they are ductile and highly corrosion resistant, permitting forming into rod and wire, use in watches and in miniature electrical and electronic components, and use in medical research work. Another alloy, cobalt-iron-vanadium, also ductile, was reported to have the highest residual induction of any known magnet material.[21] It can be electroplated. The properties of the

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[11] Dominguez, E. C., and L. H. Windsor. Leaching Burnt Pyrite Ore is New Way to Recover Cobalt. Chem. Eng., v. 71, No. 16, Aug. 3, 1964, pp. 78–80.

[12] Chemical Week. Uranium Offshoot. V. 95, No. 13, Sept. 26, 1964, p. 64.

[13] Hayashi, Masami, Donald R. Peterson, and D. W. Bridges. Electrochemical Recovery of Cobalt-Nickel Alloy From Superalloy Scrap. BuMines Rept. of Inv. 6445, 1964, 35 pp.

[14] Fraser, R. W., D. J. I. Evans, and V. N. Mackiw. The Production and Properties of Ductile Cobalt Strip. Cobalt, No. 23, June 1964, pp. 72–81.

[15] Beckers, H., L. Fontainas, B. Tougarinoff, and L. Habraken. Forming and Properties of Malleable Cobalt. Cobalt, No. 25, December 1964, pp. 171–186.

[16] Urbain, M. New Uses of Alloy UMCo–50. Development of a New Grade, UMCo–51, With Improved Stress-Rupture Strength. Cobalt, No. 23, June 1964, pp. 63–71.

[17] Freche, John C., Richard L. Ashbrook, and Gary D. Sandrock. Further Investigation of High-Temperature Cobalt-Tungsten Alloys for Aerospace Application. Cobalt, No. 24, September 1964, pp. 125–127.

[18] Chemical Engineering. Cobalt-Base Alloy. V. 71, No. 19, Sept. 14, 1964, pp. 108, 110.

[19] VanEcho, John A., and Ward F. Simmons. Mechanical and Physical Properties of Three Superalloys—MAR–M200, MAR–M302, and MAR–M322. Battelle Memorial Inst., DMIC Rept. 193, May 6, 1964, 27 pp.

[20] Metal Progress. Cobalt in High Speed Steels. V. 85, No. 6, June 1964, pp. 150, 153–156.

[21] Materials in Design Engineering. V. 59, No. 3, March 1964, p. 5.

Vicalloy-type permanent magnets (Fe-Co-V alloys) and their uses were described.[22]

A review of soft magnetic cobalt-iron alloys, their properties and possible uses, was published.[23] Two articles described columnar crystallization of magnet materials.[24] Maraging steels were reviewed and the properties of maraging stainless steels containing cobalt were described.[25]

The influence of chromium in heat resisting nickel-chromium alloys was investigated.[26] In general, chromium affects the solubility of strengthening elements, increases high temperature strength, and improves hot-working properties.

Ferronickel is a preferred material for adding nickel to steels. Because domestic ferronickel contains some cobalt, an investigation was made to determine the effect of cobalt in nickel on certain properties of austenitic stainless steels.[27]

A patent application has been made for a new process to manufacture dicobalt octocarbonyl (DO), a compound with possible large-scale usage as a catalyst or cocatalyst. It is to be prepared from oxo-alcohol and aldehyde process spent catalyst.[28]

It was reported that production of cobalt-60 may be 20 to 50 times faster using a new process of combining cobalt–59 and clay before exposing the material to radiation.[29]

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[22] Fahlenbrach, H. Properties and Fields of Application of Vicalloy-Type Permanent Magnet Alloys. Cobalt, No. 25, December 1964, pp. 187–194.

[23] Chen, C. W. Soft Magnetic Cobalt-Iron Alloys. Cobalt, No. 22, March 1964, pp. 3–21.

[24] Gould, J. E. Magnets With Columnar Crystallization. Cobalt, No. 23, June 1964, pp. 82–87.

Wright, W., and R. Ogden. Grain Growth in Alnico-Type Alloys by Solid-State Recrystallization. Cobalt, No. 24, September 1964, pp. 140–144.

[25] Hall, A. M. Review of Maraging Steel Developments. Cobalt, No. 24, September 1964, pp. 138–139, 144.

Hammond, C. M. The Development of Maraging Stainless Steels Containing Cobalt. Cobalt, No. 25, December 1964, pp. 195–202.

[26] Heslop, J. Wrought-Chromium Heat-Resisting Alloys Containing Cobalt. Cobalt, No. 24, September 1964, pp. 128–137.

[27] Tilman, M. M. Effects of Substituting Cobalt for Nickel on the Tensile Properties and Hardness of Two Types of Stainless Steel. BuMines Rept. of Inv. 6427, 1964, 16 pp.

[28] Chemical Week. New Go for DO? V. 94, No. 15, Apr. 11, 1964, p. 76.

[29] Chemical Trade Journal and Chemical Engineer (London). Speeding Up Cobalt 60 Production. V. 154, No. 4008, Apr. 3, 1964, p. 477.

Columbium and Tantalum

By Richard F. Stevens., Jr.[1]

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INTEREST in the potentials of columbium and tantalum for use in aerospace and nuclear applications continued in 1964 as indicated by extensive research on coatings and alloy development to protect these metals at elevated temperatures. Research, development, and commercial production of columbium alloys and compounds for use in superconducting magnetic coils at minus 269° C made advances.

TABLE 1.—Salient columbium-tantalum statistics

(pounds)

	1955–59 (average)	1960	1961	1962	1963	1964
United States:						
Columbium-tantalum concentrate shipped from mines [1]	234,531	----------	----------	----------	----------	----------
Production:						
Columbium metal	W	W	252,000	128,000	104,000	94,000
Tantalum metal	[2] 222,000	300,000	484,000	514,000	418,000	448,000
Ferrocolumbium and ferrotantalum-columbium	[3] 609,333	847,968	1,156,051	1,573,915	1,575,943	820,000
Consumption:						
Columbium metal contained in raw materials consumed	[3] 1,066,667	1,538,000	1,738,000	2,844,000	2,054,000	2,758,000
Tantalum metal contained in raw materials consumed	[3] 496,667	578,000	828,000	946,000	502,000	510,000
Ferrocolumbium and ferrotantalum-columbium	[4] 486,346	721,487	1,052,181	1,397,638	1,345,789	1,478,770
Imports for consumption:						
Columbium mineral concentrate	4,922,519	5,051,800	2,777,700	5,050,888	5,909,512	4,600,800
Tantalum mineral concentrate	1,147,449	709,936	1,004,151	1,211,757	944,459	980,702
Columbium metal and columbium-bearing alloys	[4] [5] 5,950	[5] 5,123	2,139	2,875	1,414	3,792
Tantalum metal and tantalum-bearing alloys			----------	----------	2,025	3,491
Exports:						
Columbium ore and concentrate	29,155	155,399	56,487	21,330	46,887	343,433
Tantalum ore and concentrate	3,772	32,406	----------	36,322	56,010	199,793
Columbium and tantalum metal, compounds, and alloys [5]	6,078	21,469	28,930	34,761	58,666	37,163
Tantalum metal powder	[4] 4,960	1,174	5,585	7,445	14,146	32,217
World: Production of columbium-tantalum concentrates	7,350,000	7,020,000	7,540,000	9,210,000	11,060,000	10,800,000

W Withheld to avoid disclosing individual company confidential data.

[1] 1956–59 data are for columbite-tantalite concentrate plus columbium-tantalum content of euxenite concentrate.

[2] Average of 1958–59 only; data for previous years unavailable.

[3] Average of 1957–59 only.

[4] Average of 1956–59 only.

[5] Columbium and tantalum metals and alloys; separate statistics not available.

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[1] Commodity specialist, Division of Minerals.

LEGISLATION AND GOVERNMENT PROGRAMS

During the year new columbium (Cb) and tantalum (Ta) stockpile objectives, deemed necessary for a 3-year conventional war, were established by the Office of Emergency Planning (OEP). On March 20, 1964, a total objective of 3.4 million pounds of tantalum was announced and on March 27, a total objective of 1,176,000 pounds for columbium was announced. On April 17, 1964, subobjectives for both columbium and tantalum were announced by OEP as follows:

Ferrocolumbium—1,690,900 pounds (lb.) gross (approx. 930,000 lb. contained Cb),
Ferrotantalum-columbium—0,
Columbium carbide powder—22,400 lb. gross (approx. 20,000 lb. contained Cb),
Columbium metal—45,000 lb.
Tantalum carbide powder—26,750 lb. gross (approx. 25,000 lb. contained Ta),
Tantalum metal—360,000 lb.

On June 5, 1964, the General Services Administration (GSA) submitted a proposal to Congress to dispose of 25,740 pounds of excess tantalum in various forms, including foil, from the national (strategic) stockpile. The proposal received congressional approval in December and GSA was expected to offer most of this material for public sale during 1965.

TABLE 2.—Columbium and tantalum items in Government inventories as of Dec. 31, 1964

(Thousand pounds, metal content)

Material	National stockpile	DPA inventory	Supplemental stockpile	Total
Stockpile grade:				
Columbium	6,029	7,890	340	14,259
Tantalum	1,633	1,471	------	3,104
(Columbium metal)[1]	(30)	------	------	(30)
(Columbium carbide powder)[1]	(21)	------	------	(21)
(Ferrocolumbium)[1]	(448)	------	------	(448)
(Ferrotantalum-columbium)[1]	(140)	------	------	(140)
(Tantalum metal)[1]	(100)	------	------	(100)
(Tantalum carbide powder)[1]	(29)	------	------	(29)
Nonstockpile grade:				
Columbium	1,336	76	32	1,444
Tantalum	1,516	65	8	1,589

[1] Figures in parentheses represent upgraded columbium and tantalum materials in inventory. They are included in the stockpile grade columbium and tantalum figures and are not in addition to them.

DOMESTIC PRODUCTION

There was no domestic mine production of columbium or tantalum during 1964.

During the year production of columbium metal powder totaled 47 tons and production of columbium metal ingots was 45 tons. The following companies produced columbium metal in 1964: E. I. du Pont de Nemours & Co., Inc., Newport, Del., and Baltimore, Md.; Fansteel Metallurgical Corp, Richmond, Calif.; Kawecki Chemical

Co., Boyertown, Pa.; Kennametal, Inc., Latrobe, Pa.; Union Carbide Metals Co., Niagara Falls, N.Y.; Union Carbide Stellite Co., Kokomo, Ind.; and Wah Chang Corp.; Albany, Oreg.

Production of tantalum metal powder (including capacitor grade powder) in 1964 totaled 224 tons and production of tantalum metal ingots was 159 tons. Fansteel Metallurgical Corp., Muskogee, Okla., Richmond, Calif., and North Chicago, Ill.; Kawecki Chemical Co.; Kennametal, Inc.; National Research Corp., Newton, Mass.; Union Carbide Metals Co., Union Carbide Stellite Co.; and Wah Chang Corp. were the principal tantalum metal producers.

Producers of ferrocolumbium, ferrotantalum-columbium, and columbium-base master alloys during 1964 were: Molybdenum Corporation of America, Washington, Pa.; Reading Alloys Co., Inc., Robesonia, Pa.; Shield-alloy Corporation, Newfield, N.J.; Union Carbide Metals Co., Niagara Falls, N.Y.; and Vanadium Corporation of America at its plants in Cambridge, Ohio, Graham, West Va., and Vancoram, Ohio. These ferro-alloys were produced in electric furnaces by Molybdenum Corp. of America, Union Carbide Metals Co., and Vanadium Corp. of America. Reading Alloys and Shieldalloy Corp. produced these ferro-alloys by the thermite process.

The Kemet Department of Linde, division of Union Carbide Corp., built and started operation of a new plant which employed about 150 people for the production of tantalum capacitors at Greenville, S.C.

Tantalum-clad copper tubing was produced by National Research Corp. The use of tantalum cladding on copper tubing combines the improved corrosion resistance and heat transfer efficiency of tantalum with the strength, rigidity, and ductility of copper.

Commercial quantities of seamless columbium and columbium-alloy tubing became available from the Wolverine Tube Division of Calumet & Hecla Co., Dearborn Heights, Mich.

Supercon Inc., Houston, Tex., one of the country's leading producers of columbium superconducting alloys, was acquired during the year by National Research Corp. and was moved to new facilities at Natick, Mass.

CONSUMPTION AND USES

Consumption of columbium metal during 1964 was primarily in ferroalloys for addition to steels to control grain size while consumption of tantalum metal was mainly in the form of ingots and powder for use in the manufacture of capacitors.

Although total consumption of columbium and tantalum in ferroalloys increased during the year, the use of ferro-columbium and ferrotantalum-columbium in high-temperature alloys, welding rods, and malleable iron castings decreased significantly. Domestic consumption of ferrocolumbium during 1964, by major use categories, was: Other alloy steels (38 percent), stainless steels (36 percent), high-temperature alloys (12 percent), carbon steels (12 percent), and welding rods, nickel-base alloys, and permanent magnet alloys (2 percent). Ferrotantalum-columbium was used in the production of stainless steels (48 percent), capacitors (29 percent), nickel-base alloys (13 percent), and high-temperature alloys (9 percent).

Additional data on ferrocolumbium and ferrotantalum-columbium are contained in the Ferroalloys chapter of this Yearbook.

Although superconducting columbium alloys and compounds continued to be offered in commercial quantities by a number of companies, the columbium consumed in this application was small.

High-purity single crystals of columbium and tantalum became available in ¼-, ⅜-, and ½-inch diameter rods up to 6 inches long from Advanced Research Materials Co., Briarcliff, N.Y.

New high-temperature materials of tantalum and columbium metal coated with zirconium diboride were developed which withstand temperatures of 2,500° to 3,500° F. for extended periods and thermal cycling far better than parts fabricated only from zirconium or titanium diboride. These new materials also possess better resistance to molten metal corrosion than does zirconium diboride.

Columbium was proposed as a replacement for silver in U.S. coins because of its large supply, ease of minting, and high intrinsic value.

General Electric Co. announced the commercial availability of GE-473, a tantalum-base alloy containing 7 to 8 percent tungsten and 2.5 to 3 percent rhenium which provides greater strength at temperatures above 3,000° F. and has excellent ductility at both extremely low and extremely high temperatures.

A packaged tantalum foil capacitor having fewer internal welds and featuring a glass-to-tantalum hermetic seal was developed by the General Electric Co., Winston-Salem, N.C.

Union Carbide Stellite Co. announced that its columbium-base alloy, Haynes Cb-753, containing 5 percent vanadium and 1.25 percent zirconium, reached production status during the year. Developed for use in the nuclear and aerospace industry, this alloy has high strength, low density, good ductility, ease of fabrication, a low nuclear cross section, and phase stability after welding.

Universal-Cyclops Steel Corp., Bridgeville, Pa., and General Electric Co., Cleveland, Ohio, installed new vacuum furnaces during the year to increase their capacity for annealing and heat treating columbium, tantalum, and other refractory metals. Universal-Cyclops will increase its columbium processing capacity by more than 3,000 pounds per load.

During 1964 Union Carbide Stellite Co. began marketing columbium, tantalum, and vanadium metal powder produced by reduction of the respective pentoxides. These metals are expected to be used principally as alloying additions.

Fansteel Metallurgical Corp. announced the acquisition of Airtek Dynamics, Inc., Compton, Calif., a company engaged in the production of aerospace components and pressure vessels and of B. M. W. Manufacturing Co., Inc., Torrance, Calif., a metal fabricator and producer of precision parts for the aerospace industry. With the acquisition of Airtek's welding, three-dimensional profile machining, drawing, sheet metal forming, testing, and manufacturing facilities, and B. M. W.'s fabrication and tool building equipment and facilities, Fansteel expanded its position as an integrated producer of refractory metals and alloys.

An improved form of tantalum, developed and offered commercially by National Research Corp., is the first to alleviate the problem of oxygen embrittlement associated with excessive grain growth. Designated SGS for stabilized grain size, this tantalum is produced by a special vacuum melting and processing technique. Its high-temperature strength is about 300 percent greater than conventionally produced tantalum at 1,650 °C. and it is available in all standard production shapes.

The patents covering the production of solid-electrolyte tantalum capacitors granted to Sprague Electric Co., North Adams, Mass., were upheld in several court decisions during the year. Sprague announced that it had granted the Kemet Department of Linde, division of Union Carbide Corp., and Cornell-Dublier Electric Co., a subsidiary of Federal-Pacific Electric Co., nonexclusive licenses "with royalties" for the manufacture of tantalum capacitors covered by Sprague patents.

TABLE 3.—Consumption by end uses of ferrocolumbium and ferrotantalum-columbium in the United States

(Pounds of contained columbium and tantalum)

Product	1963	1964
Stainless steels	450, 005	526, 265
Other alloy steels	388, 676	563, 591
Carbon steels	166, 514	178, 370
Tool steels [1]	1, 199	1, 136
Welding rods	21, 696	10, 847
Gray and malleable castings	403	90
High-temperature alloys	301, 915	180, 464
Permanent-magnet alloys	2, 976	3, 141
Miscellaneous uses [2]	12, 405	14, 866
Total	1, 345, 789	1, 478, 770

[1] Includes high-speed steels.
[2] Includes nickel-base alloys.

STOCKS

At yearend, consumers and dealers held the following inventories (in short tons): Columbite, 609; tantalite, 1,409; tin slag, 21,095; and pyrochlore, 617.

In addition, there were the following columbium inventories: Primary metal, 45,094 pounds; ingot, 39,892 pounds; scrap, 99,088 pounds; oxide, 75,953 pounds; and other columbium compounds, 39,241 pounds. Tantalum inventories included: Primary metal, 39,895 pounds; ingot, 57,760 pounds; scrap, 86,037 pounds; oxide, 54,498 pounds; potassium tantalum fluoride, 44,112 pounds; and other tantalum compounds, 33,394 pounds.

Consumer inventories of ferrocolumbium and ferrotantalum-columbium as of December 31, 1964 were: Ferrocolumbium, 385,818 pounds (contained columbium plus tantalum); and ferrotantalum-columbium, 13,723 pounds (contained columbium plus tantalum). Producer stocks of ferrocolumbium at yearend were 488,000 pounds (contained columbium plus tantalum); producer stocks of ferro-tantalum-columbium were withheld to avoid disclosing individual company confidential data.

PRICES

Prices for columbite ore, c.i.f. U.S. ports, were quoted by E&MJ Metal and Mineral Markets throughout the first part of the year at $0.90 to $1 per pound of contained pentoxides for material having a Cb_2O_5 to Ta_2O_5 ratio of 10:1, and at $0.85 to $0.90 per pound for material having a ratio of 8.5:1. In August, prices for both grades dropped by $0.10 per pound to $0.80 to $0.90 and $0.75 to $0.80, respectively, where they remained throughout the remainder of the year. During 1964, pyrochlore prices ranged from $0.92 to $1.02 per pound of Cb_2O_5, depending upon grade and quantity. Although nominal prices quoted for tantalite ores, 60 percent basis, c.i.f. U.S. ports, ranged from $6 to $7 per pound of contained pentoxides having a Ta_2O_5 to Cb_2O_5 ratio of 3:1, actual sales were reported ranging from $3 to $4.50 per pound.

Ferrocolumbium containing 50 to 60 percent columbium, 0.40 percent carbon (maximum), and 8 percent silicon (maximum) was quoted by E&MJ Metal and Mineral Markets throughout the year at $3 per pound of contained columbium, ton lots, 2-inch lump, packed and delivered. Although prices for ferrotantalum-columbium were not quoted, the producer indicated that sales were conducted at $3.05 per pound of contained columbium.

The price of columbium metal was listed at $36 per pound for roundels, 99.5 percent purity, and at $50 per pound for rough ingots, 99.5 percent purity. Tantalum metal was quoted at $30 to $49 per pound for powder, $47 to $60 per pound for sheet, and $52 to $65 per pound for rod.

TABLE 4.—Average grade of concentrate received by U.S. consumers and dealers in 1964 by country of origin

(Percent of contained pentoxides)

Country	Columbite			Tantalite	
	Cb_2O_5	Ta_2O_5	Ratio	Ta_2O_5	Cb_2O_5
Brazil	53	16	3.1 : 1	49	15
Canada [1]	51	.43	---	---	---
Congo, Republic of the	44	35	1.3 : 1	---	---
Malawi, Southern Rhodesia and Zambia	---	---	---	48	15
Malaya, Federation of	56	17	3.3 : 1	---	---
Mozambique	40	34	1.2 : 1	67	9
Nigeria	51	7	9.6 : 1	46	30
Norway [1]	56	.56	---	---	---
Portugal and Spain	52	7	7.4 : 1	34	32

[1] Pyrochlore concentrate.

FOREIGN TRADE

Imports.—Imports for consumption of columbium metal totaled 3,792 pounds, valued at $15,954, coming from the United Kingdom (81 percent) and West Germany (19 percent). Imports for consumption of tantalum metal amounted to 3,491 pounds, valued at

$52,283, coming from Austria (37 percent), Japan (32 percent), Switzerland (25 percent), West Germany (4 percent), and the United Kingdom (2 percent). In addition, some wrought tantalum metal was imported from the Netherlands.

Exports.—Reexports of columbium ore went chiefly to Japan and tantalum ore was reexported to the United Kingdom (46 percent), Japan (29 percent), the Netherlands (10 percent), Austria (7 percent), and West Germany (6 percent). Metal and powder exports went to different countries.

TABLE 5.—U.S. imports for consumption of columbium-mineral concentrates by countries

(Pounds)

Country	1955–59 (average)	1960	1961	1962	1963	1964
North America: Canada	2,800	-----	35,575	1,509,928	1,881,704	1,940,133
South America:						
Argentina	3,331	-----	-----	-----	-----	-----
Bolivia	758	-----	-----	-----	-----	-----
Brazil	137,523	126,374	73,363	95,767	1,784,558	35,478
British Guiana	1,407	-----	-----	-----	-----	-----
Total	143,019	126,374	73,363	95,767	1,784,558	35,478
Europe:						
Belgium-Luxembourg	-----	-----	-----	32,549	33,732	5,922
Denmark [1]	-----	-----	-----	-----	-----	56,217
Finland	-----	-----	-----	-----	2,207	3,307
Germany, West	181,834	6,283	-----	2,204	2,205	-----
Netherlands	2,600	35,554	-----	28,926	20,432	-----
Norway	417,060	164,486	-----	662,498	346,688	-----
Portugal	75,177	35,383	22,457	42,565	4,465	21,527
Spain	505	976	-----	-----	-----	14,610
United Kingdom	8,164	22,400	-----	56,002	-----	33,600
Total	685,340	265,082	22,457	824,744	409,729	135,183
Asia:						
Aden	270	-----	-----	-----	-----	-----
Malaysia	405,182	249,946	228,459	119,882	261,789	70,677
Thailand	2,709	-----	-----	-----	-----	-----
Total	408,161	249,946	228,459	119,882	261,789	70,677
Africa:						
British East Africa	10,231	11,670	29,971	-----	22,488	-----
Uganda						8,717
British West Africa	2,904	-----	-----	-----	-----	-----
Congo (Leopoldville)	788,049	227,724	113,085	55,846	163,437	-----
Burundi and Rwanda						7,716
Malagasy Republic	14,393	17,412	6,524	7,536	-----	21,885
Mozambique	89,187	75,851	60,613	25,453	73,498	13,228
Nigeria, Federation of	2,723,499	4,071,115	2,181,318	2,388,377	1,301,314	2,311,783
Rhodesia and Malawi	4,036	1,983	20,700	7,137	853	-----
South Africa, Republic of	37,132	4,643	2,240	4,974	10,142	56,000
Western Equatorial Africa not elsewhere classified	940	-----	-----	11,244	-----	-----
Total	3,670,371	4,410,398	2,414,451	2,500,567	1,571,732	2,419,329
Oceania: Australia	12,828	-----	3,395	-----	-----	-----
Grand total:						
Pounds	4,922,519	5,051,800	2,777,700	5,050,888	5,909,512	4,600,800
Value	$7,266,884	$3,686,549	$2,305,941	$3,419,361	$3,143,789	$2,276,536

[1] Presumably country of transshipment rather than original source.

Source: Bureau of the Census.

TABLE 6.—U.S. imports for consumption of tantalum-mineral concentrates by countries

(Pounds)

Country	1955-59 (average)	1960	1961	1962	1963	1964
South America:						
Argentina	4,854	----------	4,444	3,637	4,519	----------
Brazil	185,198	182,118	159,925	194,955	241,148	142,047
British Guiana	----------	----------	----------	----------	----------	1,103
French Guiana	8,138	----------	----------	----------	5,031	4,240
Total	198,190	182,118	164,369	198,592	250,698	147,390
Europe:						
Belgium-Luxembourg	7,789	2,426	47,993	31,896	2,137	----------
Germany, West	145,892	----------	----------	11,276	----------	----------
Netherlands	----------	8,012	26,495	----------	4,779	119,715
Norway	2,346	----------	----------	----------	----------	----------
Portugal	15,875	34,062	29,793	95,692	72,711	32,281
Spain	2,255	3,157	11,148	2,645	----------	----------
Sweden	198	----------	----------	----------	----------	----------
United Kingdom [1]	5,707	----------	----------	----------	----------	----------
Total	180,062	47,657	115,429	141,509	79,627	151,996
Asia:						
Japan	----------	----------	----------	4,401	----------	1,311
Malaysia	2,371	14,714	82,807	57,437	11,113	----------
Thailand	903	----------	----------	5,941	13,795	46,343
Total	3,274	14,714	82,807	67,779	24,908	47,654
Africa:						
British East Africa	2,646	----------	36,182	9,911	8,287	----------
Kenya						5,362
Congo (Leopoldville)	503,973	332,424	164,277	228,185	147,257	101,160
Burundi and Rwanda						2,208
Malagasy Republic	10,957	30,738	11,953	12,126	52,246	16,101
Mozambique	60,752	87,801	219,847	351,087	156,528	277,144
Nigeria, Federation of	87,424	7,698	121,110	48,551	64,831	83,710
Rhodesia and Malawi	40,371	----------	53,098	98,716	93,990	16,149
South Africa, Republic of	16,004	2,239	31,677	8,733	31,597	4,059
Western Equatorial Africa	----------	----------	----------	26,455	----------	----------
Central African Republic						472
Western Portuguese Africa	----------	----------	----------	3,490	6,746	110,494
Total	722,127	460,900	638,144	787,254	561,482	616,859
Oceania: Australia	43,796	4,547	3,402	16,623	27,744	16,803
Grand total:						
Pounds	1,147,449	709,936	1,004,151	1,211,757	944,459	980,702
Value	$1,990,617	$1,136,868	$2,001,944	$3,526,948	$2,410,814	$1,606,095

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[1] Presumably country of transshipment rather than original source.

Source: Bureau of the Census.

TABLE 7.—U.S. exports of columbium and tantalum, by classes, in 1964

Class	Pounds	Value
Columbium ores and concentrates	343,433	$188,563
Tantalum ores and concentrates	199,793	401,695
Metals and alloys in crude form and scrap	21,065	231,089
Metals and alloys in semifabricated forms	16,098	1,000,052
Tantalum metal powder	32,217	573,733

Source: Bureau of the Census.

WORLD REVIEW

NORTH AMERICA

Canada.—Shipments of pyrochlore concentrate by St. Lawrence Columbium and Metals Corp., Oka, Quebec, the sole Canadian producer increased to 4,222,424 pounds in 1964, compared with 2,692,935 pounds in 1963. Shipments to consumers in the United States decreased slightly in 1964 while those to European consumers increased substantially. All of the company's output through June 1965 was committed and it was expected that the mill, which was recently expanded to a capacity of 1,000 tons of ore per day, will be further expanded in 1965.

The primary waste product from this pyrochlore concentration operation is limestone which is sized by cyclone-type classifiers and sold as agricultural lime.[2]

Geo-Met Reactors Ltd., Ottawa, continued production of ferrocolumbium and a self-reducing columbium additive marketed under the trade name of Pycol for use in steelmaking. This additive is a mixture of pyrochlore and a reductive such as aluminum or ferrosilicon.[3]

Columbium Mining Products Ltd. estimated reserves at its property at Oka to total 100 million tons averaging 0.3 percent Cb_2O_5. Quebec Columbium Ltd., the largest property holder in the Oka area, conducted exploratory diamond-drilling.[4]

SOUTH AMERICA

Brazil.—Distribuidora e Exportadora de Mineiros e Adubas, S.A. (DEMA), the Brazilian company at Araxa, Minas Gerais, which is owned by Brazilian interests (50 percent), Wah Chang Corp. (25 percent), and Molybdenum Corporation of America (25 percent), established an agreement with Comisso Nacional de Energia Nuclear (CNEN) to export its stockpiled pyrochlore concentrate containing approximately 60 percent columbium pentoxide (Cb_2O_5). CNEN had refused to permit exportation of the pyrochlore because of its thorium content. Under the new agreement the radioactive equivalent of the thorium contained in the exported pyrochlore will be furnished to the Government of Brazil in the form of uranium oxide (yellow-cake) purchased by DEMA from South Africa.

DEMA continued the development of a ferro-columbium (FeCb) plant adjacent to the flotation mill at Araxa. This plant has provision for three thermite-type batch reactors, each capable of producing from 1½ to 2 tons of FeCb per charge. Although production was small, the company plans to develop this product since it presents no problem of thorium content necessitating a special export license from CNEN. During the processing of the pyrochlore to ferrocolumbium, the thorium remains in the slag which is stockpiled in

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[2] Northern Miner (Toronto). St. Lawrence Columbium Profits at Record Level; Sell All Output. V. 50, No. 13, June 18, 1964, pp. 1, 11.

[3] Bureau of Mines. Mineral Trade Notes. V. 56, No. 4, April 1963, p. 11.

[4] Schneider, V. B. Niobium (Columbium) and Tantalum. Dept. of Mines and Tech. Surveys, Ottawa, Canada, July 1964, 7 pp.

TABLE 8.—Free world production of columbium and tantalum concentrates (gross weight) [1] by countries [2]

(Pounds)

Country	1955–59 (average)		1960		1961		1962		1963		1964 [1]	
	Columbium	Tantalum	Columbium	Tantalum	Columbium	Tantalum	Columbium	Tantalum	Columbium	Tantalum	Columbium	Tantalum
North America:												
Canada	2,886		----------		[3] 119,261	----------	[3] 1,909,433	----------	[3] 2,692,935	----------	[3] 4,222 424	----------
United States (mine shipments)	243,531		----------		----------		----------		----------		----------	
South America:												
Argentina (U.S. imports)	8,184		----------		----------	4,444	----------	3,637	----------	4,519	----------	
Brazil (exports)	135,282	190,477	26,460	257,951	38,477	264,519	38,164	322,804	[4] 1,729,767	231,000	[5] 35,478	[5] 142,047
French Guiana	7,669		----------		----------		----------		----------	[5] 5,031	----------	[5] 4,240
Europe:												
Norway	588,849	----------	762,792	----------	708,118	----------	656,971	----------	782,633	----------	410,056	----------
Portugal (U.S. imports)	75,177	15,875	35,383	34,062	22,457	29,793	42,565	95,692	4,465	72,711	21,527	32,281
Spain (U.S. imports)	505	2,255	976	3,157	----------	11,148	----------	2,645	----------		14,610	----------
Sweden (U.S. imports)	----------	198	----------		----------		----------		----------		----------	
Asia: Malaysia	417,984	----------	208,320	----------	212,800	----------	246,400	----------	197,120	----------	125,440	----------
Africa:												
Burundi-Rwanda (U.S. imports)	(6)		(6)		(6)		(6)		(6)		----------	[5] 2,208
Congo (Léopoldville), Republic of the [6] [7]	698,417		[5] 227,724	[5] 332,424	[5] 113,085	[5] 164,277	[5] 55,846	[5] 228,185	[5] 163,437	[5] 147,257	[5] 7,716	[5] 101,160
Malagasy Republic	25,672		22,300		46,750		20,720		37,920		[8] 27,337	
Mozambique	225,021		335,487		303,166		231,437		177,867		100,684	
Nigeria	4,510,119	38,161	4,587,520	24,640	5,257,280	26,230	5,066,880	38,013	4,506,880	33,600	5,239,360	[5] 83,710
Sierra Leone	1,792		----------		----------		----------		----------		----------	
South Africa, Republic of	----------	15,660	----------	14,000	----------	20,000	----------	8,000	----------	64,000	----------	14,000
Southern Rhodesia	3,616	64,804	----------	108,080	----------	138,380	----------	159,820	----------	151,000	----------	141,320
South-West Africa	6,799	6,091	2,899	7,491	670	5,790	1,116	10,444	418	4,143	1,474	
Uganda [9]	10,640		5,226		16,240		28,851		19,841		[5] 8,717	
Oceania: Australia	53,858		23,677		31,808		43,097		30,889		• 30,000	
Free world total (estimate) [2]	7,350,000		7,020,000		7,540,000		9,210,000		[4] 11,060,000		10,800,000	

• Estimate.

[1] Frequently the composition (Cb_2O_5–Ta_2O_5) of this concentrate lies in an intermediate position, neither Cb_2O_5 nor Ta_2O_5 being strongly predominant. In such cases the production figure has been centered.

[2] This table incorporates some revisions. Data do not add exactly to totals shown because of rounding where estimated figures are included in the detail. The world total does not include the U.S.S.R. for which no production data are available.

[3] Shipments.

[4] Includes 1,687,000 pounds of pyrochlore concentrate exported to the United States. This represents a portion of 3,527,000 pounds produced in Brazil during 1961–62; similar data not available for 1964.

[5] U.S. imports.

[6] Burundi-Rwanda included in Republic of the Congo through 1963.

[7] In addition, tin-columbium-tantalum concentrate was produced as follows: 1955–59 (average) 4,457,701 pounds; 1960, estimated 1,500,000 pounds; 1961, estimated 1,400,000 pounds; 1962–64 not available; 1962, columbium-tantalum content averaging about 10 percent.

[8] Exports.

[9] In addition, tin-columbium-tantalum concentrate was produced as follows: 1955, 515 pounds.

drums for CNEN. DEMA expects to produce about 42,000 pounds of pyrochlore concentrate and 24,000 pounds of ferrocolumbium per month in 1965.

Federated Electronics, Jamaica, N.Y., acquired an option through Minex (Empresa de Exploracao de Minerios Ltda.) to purchase Brazilian mining property. Minex has been prospecting for tantalite in the territory of Rio Branco and in Nagareno, near Sao Joao del Rei, Minas Gerais.[5]

EUROPE

Belgium.—At a new factory at Hoboken, Fansteel-Hoboken, S.A., began using a new large-capacity electron-beam melting furnace to produce tantalum ingots weighing up to 600 pounds each.[6] The capacity of this plant for the production of tantalum ingots was 3.5 tons a month. Other items of equipment recently installed include a large sintering furnace and a hydrostatic press. This plant is expected to become continental Europe's first completely integrated operation capable of producing fabricated refractory metal products from the raw material.[7]

A cooperative agreement between Fansteel-Hoboken and Toleries Gantoises, Drongen, Belgium, will extend the activities of the two companies to include the manufacture of various types of equipment made from tantalum and other refractory metals.[8] Under this agreement, Fansteel-Hoboken will invest a substantial amount of capital in Toleries, a company which produces and forms specialized equipment for the chemical industry.

Portugal.—Metallium Corp., the major Portuguese tantalite producer, continued to recover tantalite as a coproduct of tin. Although the price for tantalite was low, mine production was stimulated by the high tin prices which prevailed throughout the year.[9]

ASIA

Japan.—A report issued during the year listed 15 Japanese companies which produce columbium and tantalum metal powder, columbium and tantalum oxide, tantalum carbide, and columbium and tantalum fabricated products, the processes used, and the annual capacity.[10]

The annual production capacity for tantalum metal powder reduced by heat, electrolysis, and sodium reduction of K_2TaF_7 was 33,000 pounds. The capacity for tantalum oxide produced by solvent extraction was 50,160 pounds, and the capacity for production of tantalum carbide was 26,400 pounds. Annual production capacity for fabricated tantalum products produced by powder metallurgy and arc- and electron-beam melting was 140,400 pounds. The capacity for columbium oxide produced by solvent extraction was 10,560 pounds per year, and the annual capacity for columbium products fabricated by electron-beam melting was 39,600 pounds.

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[5] Engineering and Mining Journal. V. 165, No. 4, April 1964, p. 188.

[6] Chemical Trade Journal and Chemical Engineer. Belgium Tantalum Plant in Production. V. 155, No. 4030, Sept. 4, 1964, p. 310.

[7] Metal Bulletin (London). Fansteel-Hoboken's New Furnace. No. 4899, May 26, 1964, p. 21.

[8] European Chemical News (London). Refractory Metals in Chemical Equipment. V. 6, No. 152, Dec. 11, 1964, p. 4.

[9] American Metal Market. Metallium Corp. Steps Up Its Tungsten Ore Program. V. 71, No. 94, May 14, 1964, p. 22.

[10] Japan Society of Newer Metals. Current Situation of Newer Metals in Japan. Tokyo, Japan, 1964, 45 pp.

AFRICA

Gabon, Republic of.—Columbite-tantalite deposits were explored by the Bureau de Recherche Geographique et Miniere near Tchibanga and Eteke.[11] The ores near Eteke are associated with cassiterite and those near Tchibanga are in pegmatite deposits. Some columbite-tantalite has been produced as a hand-picked byproduct of gold mining in the Eteke area.

Ghana.—The Kwame Nkrumah Steel Works near Accra has been suggested as an outlet for the large columbite deposits which have been found in the Oda and Agona Swedru areas.[12]

Rwanda.—Société Miniere de Muhinga et Kigali (Somuki) had a concession on an area near Lake Sale in southwest Rwanda which contains tin and columbium-tantalum ores. Ore from a mine in this area which was closed in 1956 contained about 32 percent Ta_2O_5 and 68 percent Cb_2O_5. The recent higher cassiterite prices and demand for columbite justify reopening of the mine.

South Africa, Republic of.—Space Metals (Pty.) Ltd., a subsidiary of Afrikander Proprietary Mines Ltd., surface mined a pegmatite deposit in the Piet Retief area of the Southeastern Transvaal region.[13] Beryl and columbite were stockpiled to accumulate sufficient tonnages for sale.

OCEANIA

Australia.—A tantalite deposit at Yalgo, Western Australia, about 250 miles north of Perth, was being developed. Tantalite ore produced was shipped to the United States.[14]

Greenbushes Tin N.L. has developed the mining and treatment techniques to be used to recover tin and tantalite by dredging at Greenbushes, Western Australia.[15] A power line to the dredge construction site has been erected, and a main access road has been constructed. Proven ore reserves totaled about 32 million cubic yards averaging 0.62 pound of tin oxide and 0.069 pound of tantalum oxide per cubic yard. Dredging operations were to start in 1965. Once the dredging operation has been established, mining by open-pit methods will be conducted in conjunction with a semimobile treatment plant.

TECHNOLOGY

A series of three Bureau of Mines reports evaluated the properties of columbium and tantalum-base alloys for use as high-temperature structural materials. One report investigated columbium-hafnium alloys and determined the optimum elevated-temperature alloys to be those containing less than 83 atomic percent of hafnium.[16]

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[11] Bureau of Mines. Mineral Trade Notes. V. 57, No. 1, July 1963, p. 5.

[12] Mining Journal (London). Columbite in Ghana. V. 260, No. 6666, May 24, 1963, p. 514.

[13] World Mining. Republic of South Africa. V. 17, No. 11, October 1964, p. 84.

[14] Metal Bulletin (London). Tantalite Find in W. Australia. No. 4928, Sept. 8, 1964, p. 20.

[15] Mining Journal (London). Australian Tin Flotation. V. 263, No. 6733, Sept. 4, 1964, p. 181.

[16] Siemens, R. E., H. R. Babitzke, and H. Kato. Columbium-Hafnium Equilibrium Diagram. BuMines Rept. of Inv. 6492, 1964, 11 pp.

The second report described investigations of hafnium-tantalum alloys.[17] This investigation indicated that the alloys of the hafnium-tantalum system had valuable elevated-temperature properties.

Following these reports, a third and more comprehensive report was issued which described studies of columbium and tantalum-base alloys suitable for high-temperature applications.[18] Sixty-nine columbium and tantalum alloys were investigated. Columbium was alloyed with two or more of the following elements, hafnium, tungsten, vanadium, titanium, and zirconium; tantalum was alloyed with vanadium, hafnium, and carbon. Of the alloys studied, the following alloys were recommended for use at elevated-temperatures on the basis of their ease of fabrication, excellent high-temperature strength, and oxidation resistance:

Columbium-15 atomic percent (a/o) hafnium-5 a/o tungsten,
Columbium-15 a/o hafnium-5 a/o tungsten-10 a/o titanium,
Columbium-15 a/o hafnium-10 a/o tungsten-10 a/o titanium,
Columbium-10 a/o vanadium-5 a/o tungsten,
Tantalum-30 a/o vanadium,
Tantalum-20 to 33 a/o hafnium.

Methods were described for analysing high-purity columbium by optical emission spectrography [19] and for determining trace quantities of tantalum in columbium by X-ray spectrography.[20]

A report on methods of extracting columbium by electrorefining processes was issued.[21] The results indicated that electrochemical refining processes were suitable for producing columbium with a purity of 99.9 percent.

Data on the thermodynamic properties of columbium carbide were published.[22]

Because the potential applications of columbium and tantalum in elevated temperature uses are limited by the refractory nature of the metals, research was conducted to develop coatings and alloying additions which would protect the metals and increase their oxidation resistance.[23]

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[17] Oden, Laurence L., D. K. Deardorff, M. I. Copeland, and H. Kato. The Hafnium-Tantalum Equilibrium Diagram. BuMines Rept. of Inv. 6521, 1964, 12 pp.

[18] Babitzke, H. R., R. E. Siemens, G. Asai, and H. Kato. Development of Columbium and Tantalum Alloys for Elevated-Temperature Service. BuMines Rept. of Inv. 6558, 1964, 33 pp.

[19] Carpenter, Lloyd, and James M. Nishi. Analysis of High-Purity Columbium by Optical Emission Spectrography. BuMines Rept. of Inv. 6414, 1964, 16 pp.

[20] Romans, P. A., W. J. Niebuhr, and J. R. Hauger. X-ray Spectrographic Analysis for Trace Quantities of Tantalum in Columbium. BuMines Rept. of Inv. 6483, 1964, 11 pp.

[21] Cummings, R. E., and F. R. Cattoir. Electrorefining of Columbium. BuMines Rept. of Inv. 6506, 1964, 12 pp.

[22] Pankratz, L. B., W. W. Weller, and K. K. Kelley. Thermodynamic Data for Columbium (Niobium) Carbide. BuMines Rept. of Inv. 6446, 1964, 9 pp.

[23] Grimm, T. C. Evaluation of LB-2 Diffusion Coatings on Tantalum. Defense Documentation Center AD 431623, Washington, D.C., March 10, 1964, 4 pp.

IIT Research Institute (Chicago, Ill.). High-Temperature Oxidation-Protective Coatings for Vanadium Base Alloys (final report). IITRI-B6019-6 (U.S. Navy Contract NOw 64-0140-c), December 1, 1964, 38 pp.

Metals and Controls, Inc. Study of Ductile Coatings for the Oxidation Protection of Columbium and Molybdenum Alloys. Defense Documentation Center AD 429754, Washington, D.C., January 31, 1964, 11 pp.

Moore, V. S., and A. R. Stetson. Evaluation of Coated Refractory Metal Foils. Defense Documentation Center AD 429810, Washington, D.C., January 20, 1964, 92 pp.

Reeves, J. C. Preliminary Evaluation of Four Columbium Base Alloys for Coating Capabilities and Mechanical Properties at Elevated Temperatures. Defense Documentation Center AD 421620, Washington, D.C., October 18, 1963, 33 pp.

Reeves, J. C. Preliminary Evaluation of Four Columbium Base Alloys for Coating Capabilities and Mechanical Properties at Elevated Temperatures. Addendum 1, Structural Brazing and Aluminide Coating. Defense Documentation Center AD 430577, Washington, D.C., February 12, 1964, 11 pp.

Warmuth, D. B., J. D. Gadd, and R. A. Jefferys. Advancement of High Temperature Protective Coatings for Columbium Alloys (II). U.S. Air Force (Thompson Ramo Wooldridge, Inc., Cleveland, Ohio), ASD-TDR-62-934 (pt. 2), April 1964, 193 pp.

A comprehensive report summarized recent data on specific silicide- and aluminide-type coatings for columbium, tantalum, and their alloys.[24] Coatings for columbium and columbium-base alloys have been developed which exceed those for molybdenum thus making columbium alloys competitive in the temperature range originally dominated by molybdenum alloys.

The resistance of refractory metals to corrosion by liquid lithium at temperatures ranging from 2,000° to 3,000° F was evaluated.[25] Under these conditions columbium metal was rated excellent, alloy FS–82 (65Cb–34Ta–1Zr) was rated good, alloy Ta–10W was rated fair, and tantalum metal was rated poor.

Columbium alloys continued to be developed under Atomic Energy Commission (AEC) contracts for use as cladding and structural materials in Nuclear Superheaters and as fuel cladding for Boiling Water Reactors,[26] because of their lack of stress corrosion, low neutron absorption cross section, strength, and resistance to boiling water corrosion. The columbium-base alloys which contained 18 to 24 atomic percent (a/o) titanium, 12 to 18 a/o vanadium, and 9 to 12 a/o chromium exhibited the best corrosion resistance to steam at 540° C.

A large columbium alloy heat transfer system successfully completed a 12-month run at 2,000° F and at a power level of 5,000 kilowatts with circulating liquid lithium as the heat transfer fluid.[27] The operation of this system, which simulated that of the SNAP–50 nuclear reactor, represented a major development in nuclear power plant technology.

Because boiling liquid metals are of interest in high performance nuclear reactor-turbine systems, studies were conducted for AEC at the Brookhaven National Laboratory (BNL) to determine the effect of molten mercury and sodium in thermal convection loops fabricated from Cb-1Zr and from pure tantalum. The columbium alloy loop was operated at 760° C. with molten mercury for 7,697 hours prior to failure. The tantalum loop has operated under identical conditions for over 9,000 hours with no indication of failure; periodic radiographs taken of this loop indicated no gross corrosion or cracking. Results of preliminary tests at BNL indicated that the Cb-1Zr alloy has good corrosion resistance to boiling sodium when the oxygen content of the sodium is limited.[28]

Fabrication techniques were developed for AEC which permitted the first successful production of thin-wall small-diameter tubing of the high strength columbium and tantalum alloys, B–66 and T–111.[29] Both alloys are designed for the optimum combination of high-temperature strength and fabricability. B–66, a columbium (5 percent molybdenum, 5 percent vanadium, 1 percent zirconium alloy) is the strongest commercially available columbium-base alloy at temperatures up to 2,500° F. on a strength-weight basis, and T–111, a tantalum (8 percent tungsten and 2 percent hafnium alloy) has yield strengths of 38,000 pounds per square inch at 2,500° F and 14,000 pounds per square inch at 3,000° F.

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[24] Gibeaut, W. A., and E. S. Bartlett. Properties of Coated Refractory Metals. Battelle Memorial Inst., Columbus, Ohio, DMIC Rept. 195, January 10, 1964, 92 pp.

[25] Bartlett, E. S., and H. R. Ogden. Summary of the Eighth Meeting of the Refractory Composites Working Group. Battelle Memorial Inst., Columbus, Ohio, DMIC Memorandum 192, April 20, 1964, 15 pp.

[26] Rice, William L. R. Nuclear Fuels and Materials Development. U.S. Department of Commerce, Clearinghouse for Federal Scientific and Technical Information, TID-11295 (3d ed.), Washington, D.C., July 1964, 301 pp.

[27] Missiles and Rockets. Liquid Lithium Loop Runs Year at 2,000° F. V. 15, No. 9, August 31, 1964, p. 17.

[28] Pages 171 to 183 of work cited in footnote 26.

[29] Pages 215 and 216 of work cited in footnote 26.

Columbium-zirconium alloys are being used as cladding materials because of their low thermal neutron cross-section, elevated-temperature strength, and compatibility with nuclear fuels. Irradiation studies of uranium sulfide (US) nuclear fuel clad in columbium-1 weight-percent zirconium (Cb-1Zr) alloy were conducted.[30] The wall thickness was such that the cladding was free standing but thin enough not to completely restrain significant dimensional changes of the fuel.

Successful methods for the consolidation of large diameter tantalum—10 percent tungsten alloy ingots and their extrusion into T-sections were reported.[31] The tantalum-tungsten billets were prepared by both electron-beam and consumable electrode arc melting techniques. Desired extrusion quality was obtained by the application of glass lubricants after heating the billets and by heating in an argon atmosphere to reduce billet contamination. The use of molybdenum cladding on the extrusion billet provided additional lubrication and allowed extrusion to be conducted at lower pressures.

Pilot production of tantalum alloys showed that ingots of Ta-10Hf-5W and Ta-30Cb-7.5V could be melted and converted to sheet bar using conventional refractory metal consolidation and fabrication procedures, that is, consumable-electrode arc melting and hot extrusion using glass lubricants.[32] Extruded rounds or sheet bars of Ta-10Hf-5W were side forged at 2,150° to 2,200° F through reductions of at least 50 percent. Extruded sheet bars of Ta-28.8Cb-7.1V alloy were finished rolled to quality sheet at 800° F. On the basis of strength-to-weight comparisions, the Ta-28.8Cb-7.1V alloy maintained superior strengths to 2,800° F. Both Ta-10Hf-5W and Ta-28.8Cb-7.1V showed excellent combinations of strength and ductility at temperatures down to —320° F. Fusion welds could be made in Ta-28.8Cb-7.1V sheet without loss in strength or ductility. Similar welds in Ta-10Hf-5W were brittle at room temperature.

Further evaluation of tantalum alloy sheet compared the weldability, high-temperature strength, and fabricability of alloys T-111 (Ta-8W-2Hf) and T-222 (Ta-9.6W-2.4Hf-0.01C).[33] Significant improvement in elevated temperature mechanical properties were achieved for the T-222 alloy without loss of either fabricability or weldability. Increasing the carbon content of T-222 from 0.01 to 0.04 percent did not improve the elevated temperature strength but did raise the weld-bend transition temperature above room temperature.

Appreciable strength increases, primarily attributed to solid-solution effects, were obtained by binary, ternary, and quaternary alloying of tungsten and tantalum in the W-Ta-Mo-Cb system.[34]

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[30] Pages 69 to 95 of work cited in footnote 26.

[31] McNadd, M., C. T. Wang, and S. A. Worcester. Tantalum Extrusion Development Program. Defense Documentation Center, AD 445841, Washington, D.C., June 1964, 98 pp.

[32] Maykuty, D. J., G. S. Root, and H. R. Ogden. Tantalum Alloy Sheet in Pilot Production. J. of Metals, v. 16, No. 2, February 1964, pp. 180–184.

[33] Ammon, R. L., and R. T. Begley. Pilot Production and Evaluation of Tantalum Alloy Sheet. Defense Documentation Center, AD 604173, Washington, D.C., July 1, 1964, 93 pp.

[34] Westgren, R. C., A. Kasak, and E. J. Dulis. Wrought Alloys of the Tungsten-Tantalum-Molybdenum-Columbium System. Trans. AIME., v. 230 (Met. Soc.), No. 6, October 1964, pp. 1284–1287.

The best combinations of strength and ductility were achieved with W-Ta-Mo alloys; the 68W-20Ta-12Mo alloy was the strongest with a tensile strength of 67,000 pounds per square inch at 3,000° F. This represents an increase of more than fourfold over the strength of unalloyed tungsten.

Studies on the effects of heat-treating and testing environments on refractory metals and alloys indicated that the residual gases, H_2, CO, N_2, and H_2O, constituted the major sources of contamination when testing columbium, tantalum, and their alloys in vacuum.[35] Methods investigated to reduce contamination during longtime, elevated-temperature exposure included: (1) Reducing the pressure or increasing the purity of the gaseous atmosphere, (2) providing a contamination barrier in the work area, or (3) utilizing a low-density gas flush to reduce contaminant gases in the work area.

A comprehensive review evaluated eight metalworking procedures applied to refractory metals.[36] Studies indicated that T-sections of the columbium-base alloy B-66 could be successfully produced by the high-velocity extrusion process using a Dynapak machine.[37] Optimum extrusions were conducted at 3,200° F with ceramic-coated ZrO_2 dies.

Two studies were conducted on the columbium-rhodium binary system. The first investigation noted that the most prominent feature of the columbium-rhodium constitution diagram was the great number of phases which appeared in the center region.[38] The Cb-Rh system was then studied to determine its similarity to the Ta-Rh, Ta-Ir, and Cb-Ir systems and to determine the crystallography of the intermediate phases found during the first investigation.[39] The tendency to form intermediate phases decreased from the Cb-Rh system, which has nine phases, to the Ta-Ir system, which has four phases.

Anodic dissolution of columbium in molten NaCl-KCl yielded sparingly soluble $CbCl_3$ at low current densities and blue solutions of Cb (IV) at high current densities whereas only Cb (IV) solutions were produced from columbium in molten LiCl-KCl.[40]

A plasma arc system has been developed which can produce spherical particles from irregularly shaped alloys of tantalum and columbium.[41] Proposed applications of the system include the making of fluidized-bed materials and maximum-flow filters for the chemical industry, nuclear fuel particles, and solid-fuel propellants.

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[40] Dartnell, J., K. E. Johnson, and L. L. Shreir. Electrochemistry of Niobium in Fused Halides. J. Less-Common Metals, v. 6, No. 2, February 1964, pp. 85–95.

[41] Chemical Engineering. Plasma System Can Make Spheres of Powdered Refractories or Alloys. V. 71, No. 4, February 17, 1964, p. 47.

Tantalum- and columbium-infiltrated materials were developed for aerospace applications by a process of powder metallurgy infiltration and liquid-phase sintering which permits the production of solid solutions of these metals at temperatures considerably lower than previously considered necessary.[42]

A cutting tool material, which contains 80 percent TiB_2 and 20 percent TaC, outlasted the best ceramic cutting tool by 2½ times while cutting steel (Rockwell C hardness 54) at a surface speed of 600 feet per minute.[43] Some of the other cutting tools which were evaluated and rated included TaN, ZrN, ZrB_2, ZrO_2, and WC.[44]

Continued interest in methods of producing and alloying columbium and tantalum was reflected by some of the patents issued in 1964.[45]

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Copper

By F. L. Wideman[1]

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THE COPPER industry established new records for production and consumption in response to demands that began to accelerate late in 1963 and that continued to be strong throughout 1964. Domestic mine production reached an alltime high in May, was impeded by strikes in the third quarter, and resumed a high rate in the final quarter. Record highs were established also in domestic smelter and refinery outputs from primary materials, and in production of copper from secondary sources. Multiple prices were an outstanding feature of the copper industry in 1964. Reflecting similar actions abroad, producers' prices in the United States rose twice during the year and closed at 34 cents per pound. In October, the price of copper exported from Chile to Europe and the United States was raised to the equivalent of 35 cents per pound, while producers' price for copper remained unchanged elsewhere. In July, dealers' prices in New York and spot prices on the London Metal Exchange began to rise above producers' prices, almost doubled by October, and began to decline almost steadily after the first week of November.

U.S. consumption of refined copper rose to 172,000 tons in June and exceeded the previous peak consumption of October 1963 by 12,000 tons. After a seasonal drop in July, use rebounded and continued at a high rate for the remainder of the year.

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[1] Commodity specialist, Division of Minerals.

Stocks of refined copper at primary producers dropped sharply until the end of June after which they turned upward moderately. Inventories at yearend were the lowest since December 1959.

Imports of all major classes of unmanufactured copper registered gains and the total was the largest in 5 years. Exports of refined copper, the chief class, were about the same as in 1963.

Despite work slowdowns and stoppages at copper producing establishments and transportation facilities, world mine production was the highest ever achieved. Increased output was reported from all major copper producing nations except Peru. Labor difficulties in Australia hampered production during the last quarter resulting in lower output from that nation.

LEGISLATION AND GOVERNMENT PROGRAMS

The U.S. District Court for the Southern District of New York ruled that the acquisition of the Okonite Company in 1958 by Kennecott Copper Corp. was in violation of Section 7 of the Clayton Antitrust Act. Kennecott appealed an order of divestiture entered on November 24, 1964, to the United States Supreme Court.[2]

On March 3, 1964, Stockpile Objective Action V–209 was amended to revise the subojectives for oxygen-free high-conductivity copper and copper content of beryllium-copper master alloys. The amendment reaffirmed the stockpile objective for copper at 775,000 tons and established within the objective the subobjectives of 67,600 tons of oxygen-free high-conductivity copper and 4,560 tons of copper as the copper content of the 9.5-million-pound objective for beryllium-copper master alloy. A total of 65,198 tons of copper was transferred to other Government agencies, principally the Bureau of the Mint, for their direct uses. On December 16, the Office of Emergency Planning announced that the Government would sell 20,000 tons of copper from the Defense Production Authority inventory.

On December 31, inventories of copper in Government stockpiles totaled 1,095,483 tons. Of this quantity, 1,008,471 tons was in the national (strategic) stockpile, 74,630 tons in Defense Production Authority inventory, and 12,382 tons in the supplemental stockpile. Included in these data were 39,701 tons of oxygen-free, high-conductivity copper in the national stockpile and 6,328 tons in the supplemental stockpile. The copper content of beryllium-copper master alloy in the national stockpile was 1,031 tons and in the supplemental stockpile, 6,054 tons. An additional 3,135 tons of oxygen-free high-conductivity copper was to be delivered to the national stockpile.

The 1.7 cent-per-pound excise tax on copper imports effective July 1, 1958, was unchanged.

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[2] Kennecott Copper Corp. Annual Report 1964. P. 15.

TABLE 1.—Salient copper statistics

	1955–59 (average)	1960	1961	1962	1963	1964
United States:						
Ore produced...thousand short tons..	118,516	134,994	142,722	150,217	146,450	155,200
Average yield of copper....percent..	0.78	0.73	0.75	0.75	0.74	0.73
Primary (new) copper produced—						
From domestic ores, as reported by—						
Mines....................short tons..	998,752	1,080,169	1,165,155	1,228,421	1,213,166	1,246,780
Value.............thousands..	$671,867	$693,468	$699,093	$756,707	$747,310	$812,901
Smelters.................short tons..	999,639	1,142,848	1,162,480	1,282,126	1,258,126	1,301,115
Percent of world total.........	25	23	23	24	23	23
Refineries..............short tons..	985,260	1,121,286	1,181,015	1,214,146	1,219,342	1,259,852
From foreign ores, matte, etc., refinery reports......short tons..	352,747	397,641	369,124	397,584	377,009	396,543
Total new refined, domestic and foreign..................short tons..	1,338,007	1,518,927	1,550,139	1,611,730	1,596,351	1,656,395
Secondary copper recovered from old scrap only...............short tons..	461,988	429,365	411,110	415,674	421,843	473,521
Imports, general:						
Unmanufactured.....short tons..	570,214	524,344	457,669	478,851	539,396	584,088
Refined....................do....	179,778	142,709	66,855	98,820	119,219	137,999
Exports:						
Metallic copper.............do....	318,552	510,494	482,824	366,585	344,960	381,432
Refined....................do....	262,551	433,762	428,718	336,525	311,479	316,230
Stocks Dec. 31: Producers:						
Refined.................short tons..	58,000	98,000	49,000	71,000	52,000	37,000
Blister and materials in solution short tons..	249,000	261,000	236,000	246,000	252,000	246,000
Total....................do....	307,000	359,000	285,000	317,000	304,000	283,000
Withdrawals (apparent) from total supply on domestic account:						
Primary copper.......short tons..	1,260,000	1,148,000	1,237,000	1,352,000	1,423,000	1,493,000
Primary and old copper (old scrap only)...............short tons..	1,722,000	1,577,000	1,648,000	1,768,000	1,845,000	1,967,000
Price: Weighted average cents per pound..	33.4	32.1	30.0	30.8	30.8	32.6
World:						
Production:						
Mine....................short tons..	3,790,000	4,650,000	4,840,000	5,100,000	5,210,000	5,420,000
Smelter....................do....	3,980,000	5,040,000	5,110,000	5,360,000	5,480,000	5,750,000
Price: London, average cents per pound..............................	33.36	30.81	28.73	29.33	29.25	43.88

DOMESTIC PRODUCTION

PRIMARY COPPER

Mine Production.—Despite extended strikes at some mines and numerous work stoppages at others, production of copper at U.S. mines increased 3 percent to 1,247,000 tons, a new record. Monthly output averaged 111,200 tons from January through June, but fell to 81,100 tons in the next 3 months as the result of closure of mines of Kennecott Copper Corp. and the White Pine Copper Co. Strikes that began at establishments of Kennecott in Arizona and Utah on July 1 ended September 9 and 19, but strikes that began at the company's mines in Nevada and New Mexico on July 8 were of shorter duration and ended August 16. A 48-day strike began September 1 at the White Pine mine. Normal operations were resumed during the last quarter, and monthly output averaged 112,100 tons.

Arizona supplied 55 percent of the total U.S. output and continued to lead all States by a wide margin. Production rose 4 percent over that of 1963 and established a new record. The Mineral Park mine, a surface mine of Duval Corp., about 15 miles northwest of Kingman, began producing in November. Autogenous grinding, the first on a large scale in Arizona, was installed in the mill circuit.

Utah continued to rank second among the major copper-producing States; however, output was 5 percent below that of 1963, and its share of the total output decreased from 17 to 16 percent. An 82-day strike at the Utah Copper Division of Kennecott Copper Corp.—the leading producer in the United States—caused the reduced output.

Montana regained third place, and its production was the largest in two decades. It increased 13 percent over that of 1963 and was 8 percent of the total U.S. output. The Anaconda Company stopped concentrating copper ore at its mill at Anaconda, Mont., at the end of October and treated all ore at the highly automated new plant at Butte. Production in New Mexico rose 4 percent despite a 39-day strike at the Chino Division of Kennecott Copper Corp. The State was in fourth place and produced 7 percent of the Nation's total. Michigan ranked fifth in mine production despite a strike at a major producer. A 17-percent decrease in output in sixth ranked Nevada was attributed largely to interruptions of mining early in the spring by slides at the Liberty Pit of Nevada Mines Division, Kennecott Copper Corp., and by a strike at the company's establishments from early July to mid-August. Output in Tennessee was practically unchanged.

Classification of production by methods showed that approximately 75 percent of the recoverable copper and 82 percent of the copper ore came from open pits. Copper produced by precipitation from mine water and leach solutions with iron was 10 percent of the mine production in 1964. Output by this method remained unchanged in Arizona, whereas decreases in Nevada and New Mexico more than offset increases in Montana and Utah.

TABLE 2.—Copper produced from domestic ores, by sources

(Short tons)

Year	Mine	Smelter	Refinery	Year	Mine	Smelter	Refinery
1960	1,080,169	1,142,848	1,121,286	1963	1,213,166	1,258,126	1,219,342
1961	1,165,155	1,162,480	1,181,015	1964	1,246,780	1,301,115	1,259,852
1962	1,228,421	1,282,126	1,214,146				

TABLE 3.—Copper ore and recoverable copper produced, by mining methods

(Percent)

Year	Open pit		Underground		Year	Open pit		Underground	
	Ore	Copper	Ore	Copper		Ore	Copper	Ore	Copper
1947	73	68	27	32	1956	78	73	22	27
1948	76	68	24	32	1957	77	72	23	28
1949	78	70	22	30	1958	76	71	24	29
1950	81	74	19	26	1959	79	74	21	26
1951	84	74	16	26	1960	80	75	20	25
1952	85	77	15	23	1961	80	74	20	26
1953	83	75	17	25	1962	81	75	19	25
1954	83	79	17	21	1963	81	74	19	26
1955	83	77	17	23	1964	82	75	18	25

TABLE 4.—Mine production of recoverable copper in the United States in 1964, by months[1]

Month	Short tons	Month	Short tons
January	107,167	August	77,502
February	107,294	September	92,193
March	111,932	October	114,535
April	111,678	November	110,047
May	115,267	December	111,772
June	113,639		
July	73,754	Total	1,246,780

[1] Monthly figures adjusted to final annual mine-production total.

Smelter Production.—Copper produced from all materials at primary smelters in the United States attained a record of 1,427,000 tons, an increase of 2 percent over output in 1963 and 1 percent more than the previous high established in 1962. A record output of 1,301,000 tons from domestic ores was partially offset by decreased production from imported material and domestic scrap.

Smelter production data are based on reports from domestic primary smelters handling copper-bearing materials. Blister copper is accounted for in terms of copper content. Production of furnace-refined copper in Michigan is included in smelter and refinery output. Metallic and cement copper recovered from leaching solutions are included in smelter production.

In August, American Smelting and Refining Company reduced operations at the smelter at Tacoma, Wash., from 7 days a week to 5 days and the work force by 6 percent. The reason given for the reductions was a shortage of copper ore resulting from Japanese smelters outbidding other processors for the limited supplies of copper ore in the world market.

Refinery Production.—Output of primary copper by the 15 primary refineries in the United States in 1964 totaled 1,656,000 tons, 3 percent more than the previous record established in 1962. Production of refined copper from secondary materials at primary plants continued a rising trend and was 16 percent more than the output from these materials in 1963.

The electrolytic plants, excluding Inspiration, had a rated annual capacity of 1,918,000 tons of refined copper and produced at 93 percent capacity.

Copper Sulfate.—Production and shipments of copper sulfate rose 1 and 6 percent, respectively. Producers' reports indicated that of the total 43,700 tons shipped, 20,900 tons was for agricultural uses, 21,700 tons for industrial uses, and 1,100 tons for other purposes, which were chiefly exports. Stocks at yearend were 38 percent less than those at the close of 1963.

Byproduct Sulfuric Acid.—Sulfuric acid produced at copper smelters from sulfide ores totaled 330,300 tons, a decrease of 8 percent from production in 1963. The data include acid produced from domestic and foreign materials and that produced at a lead smelter.

TABLE 5.—Mine production of recoverable copper in the United States, with production of maximum year, and cumulative production from earliest record to end of 1964, by States

(Short tons)

State	Maximum production [1]		Production by years						Total production from earliest record through 1964
	Year	Quantity	1955-59 (average)	1960	1961	1962	1963	1964	
Alabama	1907	42							64
Alaska	1916	59,927	8	41	92			11	686,095
Arizona	1964	690,988	478,401	538,605	587,053	644,242	660,977	690,988	19,778,651
California	1909	28,644	766	1,087	1,382	1,162	916	1,035	641,883
Colorado	1938	14,171	4,160	3,247	4,141	4,534	4,169	4,653	316,528
Georgia	1917	465							1,117
Idaho	1958	9,846	7,749	4,208	4,328	3,861	4,172	4,666	187,913
Maine	1918	383							NA
Maryland	1917	146							NA
Massachusetts	1906	5							NA
Michigan	1916	136,846	56,659	56,385	70,245	74,099	75,262	69,040	5,639,261
Missouri	1949	3,670	1,542	1,087	1,479	2,752	1,816	2,059	[2] 56,660
Montana	1916	176,464	85,215	91,972	104,000	94,021	79,762	103,806	7,961,549
Nevada	1942	83,663	72,202	77,485	78,022	82,602	81,738	67,272	2,962,348
New Hampshire	1908	[3] 94							NA
New Mexico	1964	86,104	60,692	67,288	79,606	82,683	83,037	86,104	2,591,664
North Carolina	1930	6,695		(4)	(4)	(4)	(5)		W
Oregon	1916	1.791	9	6	(4)	(4)	(5)	15	W
Pennsylvania [6]	1942	6,410	6,081	7,907	8,934	6,108	4,434	3,614	NA
South Carolina	1938	4							10
South Dakota	1918	32		1			1		108
Tennessee	1962	14,298	10,150	12,723	12,272	14,298	13,717	13,889	560,984
Texas	1928	224							1,384
Utah	1943	323,989	211,062	218,049	213,534	218,018	203,095	199,588	9,012,760
Vermont	1954	4,352	2,318						NA
Virginia	1944	291							NA
Washington	1940	9,612	1,737	78	66	41	[7] 70	35	121,927
Wisconsin	1914	5							NA
Wyoming	1900	2,102	1		1			5	16,341
Total	1964	1,246,780	998,752	1,080,169	1,165,155	1,228,421	1,213,166	1,246,780	[8] 50,864,792

NA Not available.

W Withheld to avoid disclosing individual company confidential data.

[1] For Missouri and States east of the Mississippi River, maximum since 1905.

[2] Small quantity for Wisconsin included with Missouri.

[3] The 1908 volume of Mineral Resources credits this figure to Massachusetts and New Hampshire; the 1909 volume credits it to New Hampshire alone.

[4] Included with Pennsylvania to avoid disclosing operations of individual companies.

[5] Included with Washington to avoid disclosing operations of individual companies.

[6] Includes North Carolina for 1956-62 and Oregon for 1961-62 to avoid disclosing operations of individual companies.

[7] Includes North Carolina and Oregon to avoid disclosing operations of individual companies.

[8] Largely smelter production for States east of the Mississippi River except Michigan; includes 327,545 tons for States indicated by NA.

TABLE 6.—Twenty-five leading copper-producing mines in the United States in 1964 in order of output

Rank	Mine	District or region	State	Operator	Source of copper
1	Utah Copper	West Mountain (Bingham)	Utah	Kennecott Copper Corp	Copper, gold-silver ores.
2	Morenci	Copper Mountain (Morenci)	Arizona	Phelps Dodge Corp	Do.
3	Butte Mines (includes Berkeley)	Summit Valley (Butte)	Montana	The Anaconda Company	Copper, silver-zinc ores.
4	San Manuel	Old Hat	Arizona	Magma Copper Co	Copper ore.
5	Chino	Central	New Mexico	Kennecott Copper Corp	Do.
6	Copper Queen-Lavender Pit	Warren (Bisbee)	Arizona	Phelps Dodge Corp	Do.
7	New Cornelia	Ajo	do	do	Copper, gold-silver ores.
8	Ray Pit	Mineral Creek (Ray)	do	Kennecott Copper Corp	Copper ore.
9	White Pine	Lake Superior	Michigan	White Pine Copper Co	Do.
10	Mission	Pima	Arizona	American Smelting and Refining Company	Do.
11	Inspiration	Globe-Miami	do	Inspiration Consolidated Copper Co	Do.
12	Yerington	Yerington	Nevada	The Anaconda Company	Do.
13	Liberty Pit	Robinson (Ely)	do	Kennecott Copper Corp	Do.
14	Silver Bell	Silver Bell	Arizona	American Smelting and Refining Company	Do.
15	Pima	Pima	do	Pima Mining Co	Do.
16	Esperanza	do	do	Duval Corp	Do.
17	Copper Cities	Globe-Miami	do	Tennessee Corp	Do.
18	Bagdad	Eureka (Bagdad)	do	Bagdad Copper Corp	Do.
19	Magma	Pioneer (Superior)	do	Magma Copper Co	Copper, gold-silver ores.
20	Burra-Boyd	Polk County	Tennessee	Tennessee Copper Co	Copper-zinc ore.
21	Christmas	Banner	Arizona	Inspiration Consolidated Copper Co	Copper ore.
22	Calumet & Hecla, Inc	Lake Superior	Michigan	Calumet & Hecla, Inc	Copper ore and tailings.
23	Miami	Globe-Miami	Arizona	Tennessee Corp	Copper precipitates.
24	Daisy	Pima	do	Pima Mining Co	Copper ore.
25	Cornwall	Lebanon County	Pennsylvania	Bethlehem Cornwall Corp	Magnetite-pyrite-chalcopyrite ore.

TABLE 7.—Copper ore sold or treated in the United States in 1964, with copper, gold, and silver content in terms of recoverable metals[1]

State	Ore sold or treated (short tons)	Recoverable metal content				Value of gold and silver per ton of ore
		Copper		Gold (troy ounces)	Silver (troy ounces)	
		Pounds	Percent			
Alaska	17	21,581	63.47	1	325	$26.76
Arizona	86,132,039	1,279,898,700	.74	133,983	4,915,362	.13
California	93	10,900	44.23	----------	----------	----------
Colorado	34,661	2,239,600	3.23	2,835	472,746	20.50
Idaho	71,547	2,586,000	1.81	1,220	6,075	.71
Michigan[2]	8,892,340	138,080,000	.78	----------	349,195	.05
Montana	13,613,530	196,861,700	.72	18,517	3,312,067	.36
Nevada	12,963,616	134,497,700	.52	25,379	103,337	.08
New Mexico	7,464,064	117,184,800	.78	5,251	104,744	.04
Oregon	57	23,800	20.88	28	71	18.81
Tennessee[3]	1,447,120	27,778,000	.96	133	90,539	.08
Utah	24,581,312	351,687,400	.72	243,277	2,116,401	.46
Wyoming	68	10,600	7.79	6	28	3.62
Total	155,200,464	2,250,880,781	.73	430,630	11,470,890	.19

[1] Excludes copper recovered from precipitates as follows: Arizona, 90,800,800 pounds; Montana, 8,327,800 pounds; New Mexico, 54,190,600 pounds; Utah, 42,080,300 pounds. Also excludes some copper recovered from precipitates in California; figures withheld to avoid disclosing individual company confidential data.

[2] Includes tailings.

[3] Copper-zinc ore.

TABLE 8.—Copper ore concentrated in the United States in 1964, with content in terms of recoverable copper

State	Ore concentrated (short tons)	Recoverable copper content	
		Pounds	Percent
Arizona	[1] 85,709,136	[2] 1,198,495,400	0.70
Colorado	12,679	616,500	2.43
Idaho	70,987	2,465,300	1.74
Michigan[3]	8,892,340	138,080,000	.78
Montana	13,613,426	196,846,100	.72
Nevada	[4] 8,338,059	[5] 91,413,100	.55
New Mexico	[6] 7,170,488	[7] 116,839,000	.81
Tennessee[8]	1,447,120	27,778,000	.96
Utah	24,580,381	351,610,600	.72
Total	149,834,616	2,124,144,000	.71

[1] Includes 5,836,968 tons treated by both leaching and concentration and 695,550 tons treated by heap leaching.

[2] In addition 51,044,200 pounds of copper was recovered by leaching.

[3] Includes tailings.

[4] In addition 4,573,455 tons was treated by leaching.

[5] In addition 40,130,800 pounds of copper was recovered by leaching.

[6] In addition 238,900 tons was treated by heap leaching.

[7] In addition 170,700 pounds of copper was recovered by heap leaching.

[8] Copper-zinc ore.

TABLE 9.—Copper ore shipped to smelters in the United States in 1964, with content in terms of recoverable copper

State	Ore shipped to smelters		
	Short tons	Recoverable copper content	
		Pounds	Percent
Alaska	17	21,581	63.47
Arizona	422,903	30,359,100	3.59
California	93	10,900	5.86
Colorado	21,982	1,623,100	3.69
Idaho	560	120,700	10.78
Montana	104	15,600	7.50
Nevada	52,102	2,953,800	2.83
New Mexico	[1] 54,676	175,100	.16
Oregon	57	23,800	20.88
Utah	931	76,800	4.12
Wyoming	68	10,600	7.79
Total	553,493	35,391,081	3.20

[1] Primarily smelter fluxing material.

TABLE 10.—Copper ores produced in the United States, and average yield in copper, gold, and silver

Year	Smelting ores		Concentrating ores		Total				
	Short tons	Yield in copper, percent	Short tons [1]	Yield in copper, percent	Short tons [1] [2]	Yield in copper, percent	Yield per ton in gold, ounce	Yield per ton in silver, ounce	Value per ton in gold and silver
1955-59 (average)	742,029	4.20	115,443,930	0.76	118,516,304	0.78	0.0043	0.084	$0.23
1960	669,502	3.26	134,306,380	.72	134,994,082	.73	.0040	.070	.20
1961	734,112	3.39	141,975,386	.74	142,721,798	.75	.0037	.073	.20
1962	598,519	3.25	145,580,048	.72	150,216,710	.75	.0032	.073	.19
1963	615,570	3.32	141,284,319	.72	146,449,540	.74	.0030	.070	.19
1964	553,493	3.20	149,834,616	.71	155,200,464	.73	.0028	.074	.19

[1] Includes some ore classed as copper-zinc ore.
[2] Includes copper ore leached.

TABLE 11.—Copper produced by primary smelters in the United States

(Short tons)

Year	Domestic	Foreign	Secondary	Total
1955-59 (average)	999,639	85,735	65,520	1,150,894
1960	1,142,848	90,781	74,472	1,308,101
1961	1,162,480	44,874	78,377	1,285,731
1962	1,282,126	40,488	86,903	1,409,517
1963	1,258,126	38,574	97,986	1,394,686
1964	1,301,115	37,318	88,365	1,426,798

TABLE 12.—Primary and secondary copper produced by primary refineries in the United States

(Short tons)

	1955-59 (average)	1960	1961	1962	1963	1964
Primary:						
From domestic ores, etc.:[1]						
Electrolytic	874, 090	1, 009, 983	1, 037, 489	1, 098, 032	1, 095, 377	1, 139, 494
Lake	52, 981	56, 232	70, 061	67, 072	64, 146	62, 598
Casting	58, 189	55, 071	73, 465	49, 042	59, 819	57, 760
Total	985, 260	1, 121, 286	1, 181, 015	1, 214, 146	1, 219, 342	1, 259, 852
From foreign ores, etc.:[1]						
Electrolytic	328, 370	389, 178	355, 009	379, 236	357, 015	371, 003
Casting and best select	24, 377	8, 463	14, 115	18, 348	19, 994	25, 540
Total refinery production of primary copper	1, 338, 007	1, 518, 927	1, 550, 139	1, 611, 730	1, 596, 351	1, 656, 395
Secondary:						
Electrolytic[2]	203, 898	241, 169	231, 836	237, 472	240, 620	276, 954
Casting	10, 280	10, 585	11, 294	12, 214	17, 993	23, 172
Total secondary	214, 178	251, 754	243, 130	249, 686	258, 613	300, 126
Grand total	1, 552, 185	1, 770, 681	1, 793, 269	1, 861, 416	1, 854, 964	1, 956, 521

[1] The separation of refined copper into metal of domestic and foreign origin is only approximate, as accurate separation is not possible at this stage of processing.

[2] Includes copper reported from foreign scrap.

TABLE 13.—Copper cast in forms at primary refineries in the United States

Form	1963		1964	
	Thousand short tons	Percent	Thousand short tons	Percent
Billets	213	11	222	11
Cakes	170	9	165	8
Cathodes	182	10	151	8
Ingots and ingot bars	166	9	168	9
Wirebars	1, 110	60	1, 234	63
Other forms	14	1	17	1
Total	1, 855	100	1, 957	100

TABLE 14.—Production, shipments, and stocks of copper sulfate

(Short tons)

Year	Production		Shipments	Stocks Dec. 31[1]
	Quantity	Copper content		
1955-59 (average)	60, 893	15, 223	61, 011	4, 083
1960	58, 000	14, 500	54, 272	5, 480
1961	48, 584	12, 146	46, 544	6, 740
1962	39, 984	9, 996	40, 332	5, 572
1963	41, 636	10, 409	41, 188	5, 480
1964	41, 908	10, 477	43, 684	3, 416

[1] Some small quantities are purchased and used by producing companies, so that the figures given do not balance exactly.

TABLE 15.—Byproduct sulfuric acid[1] (100-percent basis) produced in the United States

(Short tons)

Year	Copper plants[2]	Zinc plants[3]	Total
1955–59 (average)	394,798	797,547	1,192,345
1960	412,845	770,872	1,183,717
1961	362,630	776,109	1,138,739
1962	403,683	815,322	1,219,005
1963	358,503	861,763	1,220,266
1964	330,273	924,100	1,254,373

[1] Includes acid from foreign materials.

[2] Includes acid produced at a lead smelter. Excludes acid made from pyrites concentrates in Arizona, Montana, Tennessee, and Utah.

[3] Excludes acid made from native sulfur.

SECONDARY COPPER AND BRASS

Recovery of copper in the United States, in alloyed and unalloyed form, from all classes of purchased nonferrous scrap totaled 1,093,000 tons in 1964, 12 percent more than that in 1963 and 7,000 tons more than the record set in 1943. Recovery from copper-base scrap rose 12 percent at brass mills and foundries, 15 percent at primary producers 10 percent at secondary smelters, and 3 percent at chemical plants. Copper recovered from new scrap was 57 percent of the total, the same rate as in 1963.

Consumption of purchased copper-base scrap rose 11 percent in 1964. Secondary smelters consumed 399,800 tons of copper scrap, of which 314,300 tons was old scrap. Primary producers used 253,400 tons of old scrap and 231,119 tons of new material. Of 505,784 tons of scrap used at brass mills, 486,000 tons was new scrap. Foundries and other plants consumed 99,400 tons of old scrap and 23,100 tons of new scrap.

Primary copper refineries recovered 300,100 tons of refined copper, 16 percent more than that recovered in 1963. Secondary smelters recovered 50,900 tons of refined copper, and a total of 15,200 tons of copper powder castings was produced. Production of brass-mill products and output of brass and bronze ingots rose 13 percent and 7 percent, respectively.

TABLE 16.—Secondary copper produced in the United States

(Short tons)

	1955–59 (average)	1960	1961	1962	1963	1964
Copper recovered as unalloyed copper	256,943	300,259	290,805	301,374	314,643	366,197
Copper recovered in alloys[1]	640,960	571,129	558,134	620,454	659,783	726,824
Total secondary copper	897,903	871,388	848,939	921,828	974,426	1,093,021
Source:						
New scrap	435,915	442,023	437,829	506,154	552,583	619,500
Old scrap	461,988	429,365	411,110	415,674	421,843	473,521
Percentage equivalent of domestic mine output	90	81	73	75	80	88

[1] Includes copper in chemicals, as follows: 1955–59 (average), 12,886; 1960, 12,714; 1961, 10,708; 1962, 9,986; 1963, 10,191; and 1964, 7,755.

TABLE 17.—Copper recovered from scrap processed in the United States, by kind of scrap and form of recovery

(Short tons)

Kind of scrap	1963	1964	Form of recovery	1963	1964
New scrap:			As unalloyed copper:		
Copper-base	544,368	610,332	At primary plants	258,613	300,126
Aluminum-base	7,970	8,951	At other plants	56,030	66,071
Nickel-base	220	202			
Zinc-base	25	15	Total	314,643	366,197
Total	552,583	619,500	In brass and bronze	623,721	691,202
			In alloy iron and steel	2,141	2,416
Old scrap:			In aluminum alloys	23,465	25,282
Copper-base	416,493	468,336	In other alloys	265	169
Aluminum-base	4,808	4,494	In chemical compounds	10,191	7,755
Nickel-base	499	654			
Tin-base	23	22	Total	659,783	726,824
Zinc-base	20	15			
			Grand total	974,426	1,093,021
Total	421,843	473,521			
Grand total	974,426	1,093,021			

TABLE 18.—Copper recovered as refined copper, in alloys and in other forms, from copper-base scrap processed in the United States

(Short tons)

	From new scrap		From old scrap		Total	
	1963	1964	1963	1964	1963	1964
Recovered by—						
Secondary smelters	51,529	52,717	217,106	242,258	268,635	294,975
Primary copper producers	139,530	165,222	121,616	134,904	261,146	300,126
Brass mills	334,762	372,999	12,166	16,870	346,928	389,869
Foundries and manufacturers	17,338	17,998	59,379	68,053	76,717	86,051
Chemical plants	1,209	1,396	6,226	6,251	7,435	7,647
Total	544,368	610,332	416,493	468,336	960,861	1,078,668

TABLE 19.—Production of secondary copper and copper-alloy products in the United States

(Short tons)

Item produced from scrap	1963	1964
Unalloyed copper products:		
Refined copper by primary producers	258, 613	300, 126
Refined copper by secondary smelters	43, 466	50, 924
Copper powder	11, 458	13, 636
Copper castings	1, 106	1, 511
Total	314, 643	366, 197
Alloyed copper products:		
Brass and bronze ingots:		
Tin bronze	15, 929	18, 753
Leaded tin bronze	17, 053	18, 051
Leaded red brass	85, 745	92, 407
Leaded semired brass	82, 716	81, 582
High-leaded tin bronze	34, 780	38, 506
Leaded yellow brass	11, 038	12, 427
Nickel silver	3, 439	3, 877
Low brass	2, 661	2, 564
Conductor bronze	638	775
Manganese bronze	12, 369	13, 636
Aluminum bronze	8, 628	9, 259
Silicon bronze	4, 041	4, 616
Copper-base hardeners and special alloys	11, 415	15, 658
Total	290, 452	312, 111
Brass-mill products	441, 140	497, 584
Brass and bronze castings	67, 934	72, 772
Brass powder	917	1, 472
Copper in chemical products	10, 191	7, 755
Grand total	1, 125, 277	1, 257, 891

TABLE 20.—Composition of secondary copper-alloy production

(Short tons)

Year	Copper	Tin	Lead	Zinc	Nickel	Aluminum	Total
Brass and bronze production:[1]							
1963	226, 930	14, 265	19, 412	29, 222	563	60	290, 452
1964	244, 126	15, 261	20, 685	31, 321	639	79	312, 111
Secondary metal content of brass-mill products:							
1963	346, 917	151	4, 063	88, 219	1, 786	4	441, 140
1964	389, 928	335	4, 581	100, 306	2, 400	34	497, 584
Secondary metal content of brass and bronze castings:							
1963	53, 085	2, 749	8, 026	3, 992	26	56	67, 934
1964	56, 745	2, 877	8, 506	4, 599	36	9	72, 772

[1] About 95 percent from scrap and 5 percent from other than scrap.

TABLE 21.—Stocks and consumption of purchased copper scrap in the United States in 1964

(Short tons)

Class of consumer and type of scrap	Stocks Jan. 1	Receipts	Consumption			Stocks Dec. 31
			New scrap	Old scrap	Total	
Secondary smelters:						
No. 1 wire and heavy copper	2,791	38,242	1,621	37,168	38,789	2,244
No. 2 wire, mixed heavy and light copper	3,022	69,708	8,003	62,252	70,255	2,475
Composition or red brass	5,194	92,590	24,773	68,369	93,142	4,642
Railroad-car boxes	225	692		838	838	79
Yellow brass	5,750	62,970	9,301	52,954	62,255	6,465
Cartridge cases and brass	88	514		534	534	68
Auto radiators (unsweated)	3,551	55,372		53,850	53,850	5,073
Bronze	1,766	31,650	8,425	23,215	31,640	1,776
Nickel silver	725	4,189	367	3,709	4,076	838
Low brass	353	3,083	2,028	1,094	3,122	314
Aluminum bronze	166	563	131	419	550	179
Low-grade scrap and residues	4,415	41,890	30,819	9,932	40,751	5,554
Total	28,046	401,463	85,468	314,334	399,802	29,707
Primary producers:						
No. 1 wire and heavy copper	1,361	78,468	47,636	29,834	77,470	2,359
No. 2 wire, mixed heavy and light copper	5,765	166,020	95,671	66,586	162,257	9,528
Refinery brass	1,029	6,872	5,709	1,658	7,367	534
Low-grade scrap and residues	32,795	241,317	82,103	155,284	237,387	36,725
Total	40,950	492,677	231,119	253,362	484,481	49,146
Brass mills: [1]						
No. 1 wire and heavy copper	10,925	123,434	112,772	10,662	123,434	4,460
No. 2 wire, mixed heavy and light copper	3,522	47,182	47,127	55	47,182	2,575
Yellow brass	18,262	226,626	226,626		226,626	10,928
Cartridge cases and brass	2,824	54,133	45,098	9,035	54,133	2,659
Bronze	1,127	3,443	3,443		3,443	834
Nickel silver	3,293	9,406	9,406		9,406	4,176
Low brass	4,383	27,227	27,227		27,227	2,905
Aluminum bronze	342	345	345		345	326
Mixed alloy scrap	14,432	13,988	13,988		13,988	10,746
Total [1]	59,110	505,784	486,032	19,752	505,784	39,609
Foundries, chemical plants and other manufacturers:						
No. 1 wire and heavy copper	1,927	24,741	9,326	14,464	23,790	2,878
No. 2 wire, mixed heavy and light copper	1,697	20,350	5,103	15,257	20,360	1,687
Composition or red brass	1,528	3,773	1,541	2,978	4,519	782
Railroad-car boxes	2,150	41,493		41,644	41,644	1,999
Yellow brass	1,661	8,763	3,977	5,270	9,247	1,177
Auto radiators (unsweated)	1,332	10,331		8,911	8,911	2,752
Bronze	1,341	1,551	786	1,270	2,056	836
Nickel silver	20	40	1	56	57	3
Low brass	450	488	177	574	751	187
Aluminum bronze	261	559	174	314	488	332
Low-grade scrap and residues	2,166	10,030	2,076	8,634	10,710	1,486
Total	14,533	122,119	[2] 23,161	[2] 99,372	[2] 122,533	14,119

See footnotes at end of table.

TABLE 21.—Stocks and consumption of purchased copper scrap in the United States in 1964—Continued

(Short tons)

Class of consumer and type of scrap	Stocks Jan. 1	Receipts	Consumption			Stocks Dec. 31
			New scrap	Old scrap	Total	
Grand total:						
No. 1 wire and heavy copper	17,004	264,885	171,355	92,128	263,483	11,941
No. 2 wire, mixed heavy and light copper	14,006	303,260	155,904	144,150	300,054	16,265
Composition or red brass	6,722	96,363	26,314	71,347	97,661	5,424
Railroad-car boxes	2,375	42,185	----------	42,482	42,482	2,078
Yellow brass	25,673	298,359	239,904	58,224	298,128	18,570
Cartridge cases and brass	2,912	54,647	45,098	9,569	54,667	2,727
Auto radiators (unsweated)	4,883	65,703	----------	62,761	62,761	7,825
Bronze	4,234	36,644	12,654	24,485	37,139	3,446
Nickel silver	4,038	13,635	9,774	3,765	13,539	5,017
Low brass	5,186	30,798	29,432	1,668	31,100	3,406
Aluminum bronze	769	1,467	650	733	1,383	837
Low-grade scrap and residues [3]	40,405	300,109	120,707	175,508	296,215	44,299
Mixed alloy scrap	14,432	13,988	13,988	----------	13,988	10,746
Total	142,639	1,522,043	825,780	686,820	1,512,600	132,581

[1] Brass-mill stocks include home scrap; purchased scrap consumption assumed equal to receipts, so lines in brass-mill and grand total sections do not balance.

[2] Of the totals shown, chemical plants reported the following: Unalloyed copper scrap, 999 tons of new and 4,307 old; copper-base alloy scrap 1,836 tons of new and 8,585 old.

[3] Includes refinery brass.

TABLE 22.—Consumption of copper and brass materials in the United States, by principal consuming groups

(Short tons)

Year and item	Primary producers	Brass mills	Wire mills	Foundries, chemical plants, and miscellaneous users	Secondary smelters	Total
1963:						
Copper scrap	436,138	448,386	----------	112,851	362,887	1,360,262
Refined copper [1]	----------	673,907	1,036,162	30,552	3,652	1,744,273
Brass ingot	----------	6,550	22	[2] 284,629	----------	291,201
Slab zinc	----------	117,331	----------	3,370	7,536	128,237
Miscellaneous	----------	1	----------	127	8,766	8,894
1964:						
Copper scrap	484,481	505,784	----------	122,533	399,802	1,512,600
Refined copper [1]	----------	690,406	1,097,518	32,636	4,721	1,825,281
Brass ingot	----------	6,557	----------	[2] 301,987	----------	308,544
Slab zinc	----------	122,793	----------	3,812	8,490	135,095
Miscellaneous	----------	----------	----------	100	9,103	9,203

[1] Detailed information on consumption of refined copper will be found in table 27.

[2] Shipments to foundries by smelters plus decrease in stocks at foundries.

TABLE 23.—Foundry consumption of brass ingot by types, refined copper, and copper scrap, in the United States in 1964, by geographic divisions and States

(Short tons)

Geographic divisions and State	Tin bronze	Leaded tin bronze	Leaded red brass	High-leaded tin bronze	Leaded yellow brass	Manganese bronze	Hardeners	Nickel silver	Aluminum bronze	Low brass	Total brass ingot	Refined copper consumed	Copper scrap consumed
New England:													
Connecticut	158	683	3,749	96	1,943	58	25	15	278	9	7,014	451	1,476
Massachusetts	579	2,390	8,231	465	95	411	27	229	232	149	12,808	630	2,161
Maine, New Hampshire, Rhode Island, and Vermont	110	203	2,481	169	210	184	1	341	21	27	3,747	119	7
Total	847	3,276	14,461	730	2,248	653	53	585	531	185	23,569	1,200	3,644
Middle Atlantic:													
New Jersey	793	577	3,791	212	251	248	15	40	128	210	6,265	1,755	4,673
New York	707	3,060	14,218	557	512	787	63	75	1,210	147	21,336	1,141	7,565
Pennsylvania	1,104	4,597	19,712	4,079	1,259	1,312	1,669	428	648	86	34,894	5,712	12,373
Total	2,604	8,234	37,721	4,848	2,022	2,347	1,747	543	1,986	443	62,495	8,608	24,611
East North-Central:													
Illinois	709	2,521	16,905	705	89	588	191	121	878	303	23,010	2,229	6,439
Indiana	44	1,557	13,821	727	1,061	207	893	295	19	101	18,725	898	6,132
Michigan	179	285	16,799	528	460	1,794	52	7	383	60	20,547	3,452	1,714
Ohio	1,138	7,001	23,235	7,781	760	1,324	276	32	927	405	42,077	3,781	8,788
Wisconsin	1,153	546	8,101	2,307		248	450	1,002	899		15,508	6,019	1,025
Total	3,223	11,910	78,861	12,048	2,370	4,161	1,862	1,457	3,106	869	119,867	16,379	24,098

West North-Central:													
Iowa, Kansas and Minnesota	685	143	4,903	97	90	280	215	101	133	189	6,780	347	2,435
Missouri, Nebraska and South Dakota	58	216	1,501	830	616	89	14		483		3,863	468	15,073
Total	743	359	6,404	927	706	369	229	101	616	189	10,643	815	17,508
South Atlantic:													
Florida, Georgia, Delaware, District of Columbia, and Maryland	135	1,413	521	60	172	150	5	58	113	16	2,639	363	871
North Carolina, South Carolina, Virginia, and West Virginia	266	185	6,362	309	1,126	221			279		8,752	1,347	7,927
Total	401	1,598	6,883	369	1,298	371	5	58	392	16	11,391	1,710	8,798
East South-Central:													
Alabama, Kentucky, Mississippi, and Tennessee	520	584	13,042	941	3,498	362	47	44	164	103	19,305	421	6,289
West South-Central:													
Arkansas, Louisiana, Oklahoma, and Texas	279	1,104	8,929	447	621	333	96	170	585	7	12,571	186	5,279
Mountain:													
Arizona, Colorado, Idaho, Montana, Nevada, New Mexico, and Utah	112	31	313	-------	32	60	3	1	7	53	612	150	490
Pacific:													
California	492	569	9,509	704	143	482	29	125	410	64	12,414	261	12,662
Oregon and Washington	113	18	300			126	-------	-------	23		693	736	3,427
Total	605	587	9,809	704	143	608	29	125	433	64	13,107	997	16,089
Grand total	9,334	27,683	176,423	21,014	12,938	9,264	4,071	3,084	7,820	1,929	273,560	30,466	106,806

TABLE 24.—Foundry consumption of brass ingot, by types, in the United States

(Short tons)

Type of ingot	1955-59 (average)	1960	1961	1962	1963	1964
Tin bronze	13,162	9,689	11,152	9,677	8,295	9,334
Leaded tin bronze	25,236	23,818	22,876	27,034	25,655	27,683
Leaded red brass	152,455	142,817	149,405	158,047	163,153	176,423
High-leaded tin bronze	23,569	18,076	16,739	17,916	18,850	21,014
Leaded yellow brass	17,600	15,887	12,672	10,632	11,815	12,938
Manganese bronze	10,653	9,540	8,429	8,564	8,497	9,264
Hardeners	2,168	2,268	2,439	2,711	3,889	4,071
Nickel silver	3,223	2,732	2,792	3,303	2,789	3,084
Aluminum bronze	(1)	(1)	(1)	7,688	8,053	7,820
Low brass [2]	7,823	7,365	7,505	928	1,316	1,929
Total	255,889	232,192	234,009	246,500	252,312	273,560

[1] Included with low brass.

[2] Includes aluminum bronze for 1955-61.

TABLE 25.—Dealers' monthly average buying price for copper scrap and consumers' alloy-ingot prices at New York in 1964

(Cents per pound)

Grade	Jan.	Feb.	Mar.	Apr.	May	June
No. 2 copper scrap	24.00	24.45	25.69	27.04	27.60	25.43
No. 1 composition scrap	21.16	21.70	22.94	24.25	24.72	23.00
No. 1 composition ingot	32.00	32.00	32.50	33.82	34.00	34.00

	July	Aug.	Sept.	Oct.	Nov.	Dec.	Average
No. 2 copper scrap	25.52	28.18	29.00	32.32	34.62	33.40	28.10
No. 1 composition scrap	23.32	25.60	25.92	28.36	29.36	28.34	24.89
No. 1 composition ingot	34.00	34.93	35.99	37.92	40.25	40.25	35.14

Source: Metal Statistics, 1965.

CONSUMPTION

Apparent withdrawals of primary copper rose 5 percent in 1964. Demand for copper was strong throughout the year, and consumption of new copper was the largest since 1944.

Actual consumption of refined copper increased 5 percent to 1,825,300 tons, the highest since compilation of the data began in 1945. These data are based on consumers' reports of quantities entering processing, with no adjustments of stock changes of material in process. Unlike table 26, in which only new copper is included as far as possible, table 27 does not distinguish between old and new copper, but includes all copper in refined form.

Distribution of actual consumption by principal use-groups followed the usual pattern with wire mills consuming 60 percent and brass mills 38 percent of the total. Consumption exceeded 147,600 tons in January and rose to 172,000 tons in June. Because of annual vacations at consuming plants, use dropped to 114,200 tons in July, but recovered briskly in August and was more than 156,400 tons in December.

TABLE 26.—Primary refined-copper supply and withdrawals on domestic account

(Short tons)

Supply and withdrawals	1955-59 (average)	1960	1961	1962	1963	1964
Production from domestic and foreign ores, etc.	1,338,007	1,518,927	1,550,139	1,611,730	1,596,351	1,656,395
Imports [1]	183,673	142,709	66,855	98,820	[r] 119,219	137,999
Stock Jan. 1 [1]	59,000	18,000	98,000	49,000	71,000	52,000
Total available supply	1,580,680	1,679,636	1,714,994	1,759,550	[r] 1,786,570	1,846,394
Copper exports [1]	262,551	433,762	428,718	336,525	311,479	316,230
Stock Dec. 31 [1]	58,000	98,000	49,000	71,000	52,000	37,000
Total	320,551	531,762	477,718	407,525	363,479	353,230
Apparent withdrawals on domestic account [2]	1,260,000	1,148,000	1,237,000	1,352,000	1,423,000	1,493,000

[r] Revised.

[1] May include some copper refined from scrap.

[2] Includes copper delivered by industry to the government stockpiles.

TABLE 27.—Refined copper consumed, by classes of consumers

(Short tons)

Year and class of consumer	Cathodes	Wire bars	Ingots and ingot bars	Cakes and slabs	Billets	Other	Total
1963:							
Wire mills		1,024,093	11,271			798	1,036,162
Brass mills	145,271	44,250	87,832	186,876	209,576	102	673,907
Chemical plants			726			512	1,238
Secondary smelters	1,906		1,731	11		4	3,652
Foundries	3,575	118	7,584	12	413	1,450	13,152
Miscellaneous [1]	1,163		9,114	23	572	5,290	16,162
Total	151,915	1,068,461	118,258	186,922	210,561	8,156	1,744,273
1964:							
Wire mills		1,086,215	10,424			879	1,097,518
Brass mills	129,944	44,756	111,506	184,434	219,651	115	690,406
Chemical plants			1,621			550	2,171
Secondary smelters	2,291		2,308	9		113	4,721
Foundries	3,792	61	9,654		310	1,122	14,939
Miscellaneous [1]	1,023	38	7,565	(2)	700	[3] 6,200	15,526
Total	137,050	1,131,070	143,078	184,443	220,661	8,979	1,825,281

[1] Includes iron and steel plants, primary smelters producing alloys other than copper, consumers of copper powder and copper shot, and miscellaneous manufacturers.

[2] Included with "other" to avoid disclosing individual company confidential data.

[3] Includes "cakes and slabs" to avoid disclosing individual company confidential data.

STOCKS

A high rate of consumption, which exceeded production, caused stocks held by primary producers in the United States to drop from 52,000 tons on January 1, 1964, to 31,600 tons on July 31. During the last 7 months of the year, consumption continued at a high rate and together with losses of production hindered replenishment of inventories. Yearend stocks totaled 37,000 tons and were the lowest since December 31, 1959. Stocks of unrefined material decreased 2 percent.

TABLE 28.—Stocks of copper at primary smelting and refining plants in the United States, Dec. 31

(Short tons)

Year	Refined copper [1]	Blister and materials in process of refining [2]	Year	Refined copper [1]	Blister and materials in process of refining [2]
1955–59 (average)	58,000	249,000	1962	71,000	246,000
1960	98,000	261,000	1963	52,000	252,000
1961	49,000	236,000	1964	37,000	246,000

[1] May include some copper refined from scrap.
[2] Includes copper in transit from smelters in the United States to refineries therein.

Fabricators' stocks of refined copper, including in-process metal and fabricated shapes, were 430,000 tons at yearend, 9 percent less than stocks at the beginning of the year. Working stocks on December 31 were 381,700 tons, 1,000 tons less than stocks on January 1.

TABLE 29.—Stocks of copper in fabricators' hands Dec. 31

(Short tons)

Year	Stocks of refined copper [1] (1)	Unfilled purchases of refined copper from producers (2)	Working stocks (3)	Unfilled sales to customers (4)	Excess stocks over orders booked [2] (5)
1960	456,094	75,222	370,055	126,260	35,001
1961	461,252	89,745	361,286	144,344	45,367
1962	465,592	81,297	385,239	138,089	23,561
1963	474,875	100,357	382,692	163,558	28,982
1964	429,989	107,244	381,677	225,366	−69,810

[1] Includes in-process metal and primary fabricated shapes. Also includes small quantities of refined copper held at refineries for fabricators' account.
[2] Columns (1) plus (2) minus (3) and minus (4) equal column (5).

Source: United States Copper Association.

PRICES

Reports from copper-selling agencies indicated that 1,469,061 tons of domestic copper was delivered to purchasers at an average price of 32.6 cents per pound. The average price for foreign copper delivered in the United States was 33.0 cents per pound.

The first change in the price of copper since May 19, 1961, occurred March 13 when the two large producers in Zambia (Northern Rhodesia) announced they had increased their fixed selling price by 1 cent per pound. On the same day a producer in the United States posted a spot selling price of 32 cents per pound. Other large producers in the United States and abroad increased their prices 1 cent per pound effective March 16 or soon thereafter. The price of copper produced in the United States was increased 2 cents per pound on September 22, thus establishing the U.S. producers' price at 34 cents per pound. Effective October 6, the price of copper exported from Chile for sale in Europe advanced to 35 cents per pound, 2½ cents more than producers' price for foreign copper elsewhere in the free world. On October 26, the price of Chilean-produced copper sold in the United States was increased to 35 cents per pound.

The price of copper on commodity exchanges in the U.S. and abroad fluctuated widely. Near midyear, dealers' prices for spot copper began to exceed producers' prices. Quotes for dealers copper continued to rise and by mid-November reached 65 cents per pound. Quotes began to decline in early December and were above 50 cents by yearend.

London Price.—Quotations on the London Metal Exchange were trending upward at the beginning of the year and, except for a brief decline in June and July, continued upward reaching a record high of 65.235 cents per pound on December 9, after which they began to decline. The average monthly price ranged from £237 13s. 5d. per long ton (29.69 cents per pound) in January to an alltime high monthly average for November of £506 14s. 1d. (62.99 cents). The average price for December was £458 16s, 2d. (57.16 cents). The average for the year was 50 percent more than that in 1963.

TABLE 30.—Average weighted prices of copper deliveries,[1] consumer plants

(Cents per pound)

Year	Domestic copper	Foreign copper	Year	Domestic copper	Foreign copper
1960	32.1	32.5	1963	30.8	30.7
1961	30.0	30.4	1964	32.6	33.0
1962	30.8	30.6			

[1] Covers copper produced in the United States and delivered here and abroad and copper produced abroad and delivered in the United States; excludes copper both produced and delivered abroad, whether or not handled by U.S. selling agencies.

TABLE 31.—Average monthly quoted prices of electrolytic copper for domestic and export shipments, f.o.b. refineries, in the United States and for spot copper at London

(Cents per pound)

Month	1963				1964			
	Domestic, f.o.b. refinery [1]	Domestic, f.o.b. refinery [2]	Export, f.o.b. refinery [2]	London, spot [3] [4]	Domestic, f.o.b. refinery [1]	Domestic, f.o.b. refinery [2]	Export, f.o.b. refinery [2]	London, spot [3] [4]
January	30.82	30.600	28.433	29.32	30.82	30.600	28.566	29.69
February	30.82	30.600	28.439	29.30	30.82	30.600	28.629	31.40
March	30.82	30.600	28.400	29.27	31.35	31.116	29.127	33.74
April	30.82	30.600	28.404	29.28	31.82	31.600	29.636	39.01
May	30.82	30.600	28.405	29.26	31.82	31.600	29.670	37.49
June	30.82	30.600	28.396	29.27	31.82	31.600	29.830	36.53
July	30.82	30.600	28.397	29.28	31.82	31.600	29.960	38.58
August	30.82	30.600	28.409	29.26	31.82	31.600	30.977	45.01
September	30.82	30.600	28.390	29.24	32.44	32.230	32.694	52.19
October	30.82	30.600	28.389	29.24	33.82	33.607	34.141	61.05
November	30.82	30.600	28.380	29.25	33.82	33.664	34.192	62.99
December	30.82	30.600	28.515	29.42	33.82	33.701	34.392	57.16
Average	30.82	30.600	28.413	29.25	32.17	31.960	30.985	43.88

[1] American Metal Market.
[2] E&MJ Metal and Mineral Markets.
[3] Metal Bulletin (London).
[4] Based on average monthly rates of exchange by Federal Reserve Board.

FOREIGN TRADE

Imports.—Entries of crude and refined copper into the United States increased 8 percent and were the highest since 1959. Nations of the Western Hemisphere supplied 85 percent of the total as follows: Chile, 44 percent; Peru, 19 percent; Canada, 19 percent; Mexico, 2 percent; Bolivia and Ecuador, 1 percent. Imports of copper in ore and concentrate increased 7 percent and Canada supplied 48 percent of these imports. Increases in imports of blister copper from Chile and the Republic of South Africa more than offset decreases from Peru and Mexico, resulting in a 6-percent increase in receipts of this material. Imports of refined copper increased 16 percent. Canada supplied 62 percent and Peru, 21 percent of the imports of this class.

Imports of scrap in 1964 rose 56 percent.

Exports.—Refined copper continued as the principal class of exports and shipments increased 2 percent over shipments in 1963. West Germany, Italy, and the United Kingdom were major recipients, but substantial shipments went to other countries, chiefly France, India, and Japan.

Exports of copper scrap increased more than threefold and exports of copper-base scrap almost doubled. Japan received 44 percent of the copper scrap and 77 percent of copper-base scrap exported.

Tariff.—The price of copper remained above 24 cents per pound in 1964 and the 1.7 cent-per-pound excise tax, effective July 1, 1958, was applicable to imported copper.

TABLE 32.—U.S. imports[1] of copper (unmanufactured), by classes and countries

(Short tons, copper content)

Year and country	Ore and concentrates	Matte	Blister	Refined	Scrap	Total
1955-59 (average)	102,228	7,106	273,629	179,778	7,473	570,214
1960	75,518	5,049	298,373	142,709	2,695	524,344
1961	45,788	1,606	339,189	66,855	4,231	457,669
1962	42,917	635	331,686	98,820	4,793	478,851
1963:						
North America:						
Canada	[r] 15,490	190	50	[r] 73,180	[r] 1,760	[r] 90,670
Mexico	275	126	21,885	-----	58	22,344
Other	-----	2	-----	-----	195	197
Total	[r] 15,765	318	21,935	[r] 73,180	[r] 2,013	[r] 113,211
South America:						
Chile	[r] 590	[r] 161	[r] 219,183	6,729	338	[r] 227,001
Peru	[r] 8,720	325	81,083	9,450	-----	[r] 99,578
Other	1,462	65	-----	23	50	1,600
Total	[r] 10,772	[r] 551	[r] 300,266	16,202	388	[r] 328,179
Europe:						
Belgium-Luxembourg	-----	-----	-----	12,653	4	12,657
United Kingdom	-----	-----	-----	815	249	1,064
Other	-----	-----	-----	332	132	464
Total	-----	-----	-----	13,800	385	14,185
Asia:						
Philippines	14,869	38	-----	-----	-----	14,907
Other	-----	-----	-----	47	43	90
Total	14,869	38	-----	47	43	14,997

See footnotes at end of table.

TABLE 32.—U.S. imports[1] of copper (unmanufactured), by classes and countries—Continued

(Short tons, copper content)

Country	Ore and concentrates	Matte	Blister	Refined	Scrap	Total
1963—Continued						
Africa:						
Rhodesia and Malawi	---	---	[r]15,390	11,191	---	[r]26,581
South Africa, Republic of	4,946	---	31,309	94	19	36,368
Other	---	---	---	4,698	---	[r]4,698
Total	4,946	---	46,699	15,983	19	67,647
Oceania:						
Australia	1,149	---	---	---	---	1,149
Other	---	---	---	7	21	28
Total	1,149	---	---	7	21	1,177
Grand total	[r]47,501	[r]907	[r]368,900	[r]119,219	[r]2,869	[r]539,396
1964:						
North America:						
Canada	25,005	35	2	84,930	1,104	111,076
Mexico	1,026	---	12,386	112	549	14,073
Other	---	2	---	(2)	277	279
Total	26,031	37	12,388	85,042	1,930	125,428
South America:						
Chile	1,767	311	251,092	917	2,428	256,515
Peru	8,041	203	75,664	28,502	---	112,410
Other	1,492	36	956	---	52	2,536
Total	11,300	550	327,712	29,419	2,480	371,461
Europe:						
Belgium-Luxembourg	---	---	1,087	961	---	2,048
Norway	---	---	61	773	---	834
United Kingdom	---	---	---	2,516	4	2,520
Other	---	---	---	1,135	16	1,151
Total	---	---	1,148	5,385	20	6,553
Asia:						
India	---	---	---	330	---	330
Philippines	9,472	15	---	---	---	9,487
Other	---	---	1,109	---	43	1,152
Total	9,472	15	1,109	330	43	10,969
Africa:						
Rhodesia and Malawi	---	---	7,393	11,980	---	19,373
South Africa, Republic of	3,607	---	39,162	1,105	---	43,874
Other	11	---	667	4,738	---	5,416
Total	3,618	---	47,222	17,823	---	68,663
Oceania: Australia	1,014	---	---	---	---	1,014
Grand total	51,435	602	389,579	137,999	4,473	584,088

[r] Revised.

[1] Data are "general" imports, that is, they include copper imported for immediate consumption plus material entering the country under bond.

[2] Less than ½ unit.

Source: Bureau of the Census.

TABLE 33.—U.S. imports[1] of copper (unmanufactured), by countries

(Short tons, copper content)

Country	1955–59 (average)	1960	1961	1962	1963	1964
North America:						
Canada	106,976	117,641	78,354	98,753	[r] 90,670	111,076
Mexico	45,948	22,656	20,963	23,779	22,344	14,073
Other	16,589	6,758	308	368	197	279
Total	169,513	147,055	99,625	122,900	[r] 113,211	125,428
South America:						
Bolivia	3,490	1,346	905	1,580	1,520	1,492
Chile	228,190	208,167	226,971	225,394	[r] 227,001	256,515
Peru	34,949	91,624	90,435	72,133	[r] 99,578	112,410
Other	641	11	(2)	28	80	1,044
Total	267,270	301,148	318,311	299,135	[r] 328,179	371,461
Europe:						
Belgium-Luxembourg	2,038	2,673	---	---	12,657	2,048
France	1,218	526	---	1	125	4
Germany, West	7,479	8,739	14	---	2	268
Netherlands	689	506	---	23	334	502
Norway	1,238	248	---	---	---	834
United Kingdom	7,608	781	1,316	846	1,064	2,520
Other	8,291	7,939	11	724	3	377
Total	28,561	21,412	1,341	1,594	14,185	6,553
Asia:						
Philippines	13,128	17,562	13,898	10,126	14,907	9,487
Turkey	2,363	547	---	---	---	1,109
Other	232	2	---	35	90	373
Total	15,723	18,111	13,898	10,161	14,997	10,969
Africa:						
Rhodesia and Malawi	42,849	5,795	10	18,997	[r] 26,581	19,373
South Africa, Republic of	22,895	28,228	23,474	24,460	36,368	43,874
Other	11,626	821	21	784	[r] 4,698	5,416
Total	77,370	34,844	23,505	44,241	67,647	68,663
Oceania:						
Australia	11,777	1,774	826	751	1,149	1,014
Other	(2)	---	163	69	28	---
Total	11,777	1,774	989	820	1,177	1,014
Grand total	570,214	524,344	457,669	478,851	[r] 539,396	584,088

[r] Revised.

[1] Data are "general" imports; that is, they include copper imported for immediate consumption plus material entering the country under bond.

[2] Less than ½ unit.

Source: Bureau of the Census.

TABLE 34.—U.S. imports for consumption of old brass and clippings from brass or Dutch metal [1]

Year	Short tons		Value (thousands)	Year	Short tons		Value (thousands)
	Gross weight	Copper content			Gross weight	Copper content	
1955–59 (average)	7,001	4,541	$2,623	1962	2,141	1,289	$738
1960	566	309	184	1963	1,516	945	558
1961	608	390	173	1964	989	641	415

[1] For remanufacture.

Source: Bureau of the Census.

TABLE 35.—U.S. imports for consumption of copper (copper content), by classes [1]

Year	Ore and concentrates		Matte		Blister		Refined		Scrap		Total value (thousands)
	Short tons	Value (thousands)	Short tons	Value (thousands)	Short tons	Value (thousands)	Short tons	Value (thousands)	Short tons	Value (thousands)	
1955–59 (average)	75,345	$44,848	5,797	$3,711	193,950	$130,779	183,673	$123,344	6,533	$3,971	$306,653
1960	24,438	14,407	185	80	486	311	171,021	109,490	1,836	1,106	125,394
1961	24,501	14,042	95	57	5,929	3,508	87,206	51,852	1,643	870	70,329
1962	2,322	1,414	22	12	1,119	669	130,197	76,995	3,846	2,242	81,332
1963	[r] 6,490	[r] 3,714	[r] 2,756	[r] 1,647	[r] 21,831	[r] 13,109	[r] 122,147	[r] 70,818	[r] 2,130	1,219	[r] 90,507
1964	42,936	19,845	107	675	121,365	73,300	110,273	65,652	5,195	3,118	162,590

[r] Revised.

[1] Excludes imports for manufacture in bond and export, classified as "imports for consumption" by the Bureau of the Census.

Source: Bureau of the Census.

TABLE 36.—U.S. exports of copper by classes and countries

(Short tons)

Year and destination	Ore, concentrates, matte (copper content)	Refined	Scrap	Pipes and tubing	Plates and sheets	Wire and cable, bare	Wire and cable, insulated	Other copper manufactures
1955-59 (average)	11, 345	262, 551	27, 678	1, 321	325	7, 521	19, 158	1, 908
1960	11, 111	433, 762	58, 860	726	500	3, 278	13, 368	5, 181
1961	4, 478	428, 718	35. 257	949	355	1, 995	15, 550	7, 362
1962	1, 916	336, 525	12, 608	864	349	2, 875	13, 364	6, 768
1963	1, 210	311, 479	13, 690	1. 158	338	3, 150	15, 145	5, 811
1964:								
North America:								
Canada	158	7, 908	1, 567	363	85	180	2, 063	747
Mexico	--------	3	8	57	69	109	184	18
Other	--------	23	11	266	25	209	2, 243	656
Total	158	7, 934	1, 586	686	179	498	4, 490	1, 421
South America:								
Argentina	--------	5. 738	113	3	1	53	163	9
Brazil	--------	3, 913	--------	8	2	(1)	92	19
Colombia	--------	20	--------	27	3	47	301	682
Venezuela	--------	42	--------	59	11	14	177	1, 480
Other	--------	44	--------	31	7	74	1, 460	3
Total	--------	9, 757	113	128	24	188	2, 193	2, 193
Europe:								
Belgium-Luxembourg	--------	1, 001	4, 495	4	--------	12	79	1
France	--------	34, 608	3	2	2	23	78	50
Germany, West	1, 816	58, 806	5, 741	64	--------	3	172	30
Italy	--------	55, 454	636	15	8	9	139	22
Netherlands	56	5, 394	524	4	7	21	210	--------
Norway	--------	4, 261	--------	7	--------	3	11	--------
Spain	--------	1, 078	6, 904	6	--------	21	215	--------
Sweden	353	3, 868	212	6	--------	14	49	32
Switzerland	--------	3, 398	--------	5	--------	90	26	--------
United Kingdom	1, 029	54, 929	132	2	32	34	36	31
Yugoslavia	--------	--------	2, 119	(1)	4	--------	78	--------
Other	--------	1, 988	98	16	(1)	63	155	--------
Total	3, 254	224, 785	20, 864	131	53	293	1, 248	166
Asia:								
India	1, 646	47, 219	1, 137	95	65	2, 424	980	1
Japan	335	20, 621	19 138	9	17	1	153	--------
Taiwan	--------	128	126	14	1	15	59	--------
Viet-Nam, South	--------	1	--------	13	5	193	765	17
Other	2	666	27	281	49	1 259	3. 091	647
Total	1, 983	68, 635	20, 428	412	137	3, 892	5, 048	665
Africa	--------	19	758	73	3	199	1, 214	15
Oceania	--------	5, 100	--------	3	2	116	243	10
Grand total	5, 395	316, 230	43, 749	1, 433	398	5, 186	14, 436	4, 470

[1] Less than ½ unit.

Source: Bureau of the Census.

TABLE 37.—U.S. exports of copper by classes

Year	Ore, concentrates, and matte (copper content)		Refined copper and semimanufactures		Other copper manufactures		Total	
	Short tons	Value	Short tons	Value	Short tons	Value	Short tons	Value
1955–59 (average)	11,345	$7,752,751	318,552	$221,327,521	1,908	$1,506,979	331,805	$230,587,251
1960	11,111	6,832,050	510,494	327,935,628	5,181	4,006,049	526,786	338,773,727
1961	4,478	2,474,679	482,824	295,397,080	7,362	5,260,315	494,664	303,132,074
1962	1,916	1,045,181	366,585	234,604,915	6,768	5,106,603	375,269	240,756,699
1963	1,210	638,177	344,960	225,648,628	5,811	4,273,403	351,981	230,560,208
1964	5,395	2,970,822	381,432	262,741,291	4,470	3,667,512	391,297	269,379,625

Source: Bureau of the Census.

TABLE 38.—U.S. exports of copper-base alloy (including brass and bronze), by classes

Class	1963		1964	
	Short tons	Value	Short tons	Value
Ingots	592	$639,883	1,987	$2,040,846
Scrap and other forms	34,717	14,606,864	68,670	33,580,336
Bars, rods, and shapes	787	1,142,617	1,041	1,504,435
Plates, sheets, and strips	667	1,708,756	1,114	2,510,768
Pipes and tubing	2,119	3,254,869	1,366	2,154,755
Pipe fittings	1,129	2,859,190	1,529	3,477,341
Plumbers' brass goods	2,341	6,302,835	2,729	7,054,779
Welding rods and wire	973	1,993,378	941	2,255,560
Castings and forgings	569	1,254,468	668	1,312,192
Powder	541	678,012	475	632,267
Semifabricated forms, not elsewhere classified	59	146,414	93	181,503
Total	44,494	34,587,286	80,613	56,704,782

Source: Bureau of the Census.

TABLE 39.—U.S. exports of unfabricated copper-base alloy[1] ingots, bars, rods, shapes, plates, sheets, and strips

Year	Short tons	Value	Year	Short tons	Value
1955–59 (average)	1,804	$3,018,298	1962	2,391	$4,227,640
1960	1,920	4,235,521	1963	2,046	3,491,256
1961	1,705	3,658,503	1964	4,142	6,056,049

[1] Includes brass and bronze.

Source: Bureau of the Census.

TABLE 40.—U.S. exports of copper sulfate (blue vitriol)

Year	Short tons	Value	Year	Short tons	Value
1955–59 (average)	22,224	$4,960,510	1962	1,916	$455,665
1960	14,841	3,376,649	1963	851	[r] 226,758
1961	7,575	1,542,212	1964	1,087	275,477

[r] Revised.

Source: Bureau of the Census.

TABLE 41.—U.S. imports and exports of brass and copper scrap

(Short tons)

	1955-59 (average)	1960	1961	1962	1963	1964
Imports for consumption:						
Brass scrap (gross weight)	7,001	566	608	2,141	1,516	989
Copper scrap (copper content)	6,533	1,836	1,643	3,846	[r] 2,130	5,195
Exports:						
Copper-base alloy scrap (new and old)	44,730	122,175	116,654	36,209	34,717	68,670
Copper scrap	27,678	58,860	35,257	12,608	13,690	43,749

[r] Revised.

Source: Bureau of the Census.

TABLE 42.—U.S. imports for consumption and exports of copper scrap, by countries

(Short tons)

Country	Imports				Exports			
	Unalloyed copper scrap (copper content)		Copper alloy scrap (gross weight)		Unalloyed copper scrap		Copper alloy scrap	
	1963	1964	1963	1964	1963	1964	1963	1964
North America:								
Canada	[r] 1,385	1,081	1,133	768	283	1,567	292	448
Mexico	58	549	50	21	(1)	8	36	37
Other	189	271	211	199	21	11	-	34
Total	1,632	1,901	1,394	988	304	1,586	328	519
South America	1	3,185	9	-	-	113	10	14
Europe:								
Belgium-Luxembourg	-	-	-	-	39	4,495	120	724
France	-	45	-	-	-	3	418	550
Germany, West	(1)	5	-	-	39	5,741	725	8,290
Italy	-	-	-	-	49	636	218	793
Netherlands	3	4	-	-	38	524	2	406
Spain	-	-	-	-	1,126	6,904	61	321
Sweden	-	-	1	-	30	212	765	2,934
United Kingdom	249	4	112	-	-	132	95	594
Yugoslavia	-	-	-	-	3,727	2,119	-	-
Other	7	8	-	1	-	98	-	35
Total	259	66	113	1	5,048	20,864	2,404	14,647
Asia:								
India	-	-	-	-	385	1,137	205	139
Japan	43	43	-	-	7,924	19,138	31,623	53,150
Other	-	-	-	-	29	153	145	114
Total	43	43	-	-	8,338	20,428	31,973	53,403
Africa	174	-	-	-	-	758	2	11
Oceania	21	-	-	-	-	-	-	76
Grand total	[r] 2,130	5,195	1,516	989	13,690	43,749	34,717	68,670

[r] Revised.
[1] Less than ½ unit.

Source: Bureau of the Census.

WORLD REVIEW

A buoyant economy in the free world created an increased demand for copper, which was estimated to be 10 percent higher than that of 1963. The copper industry returned to full production early in 1964, but strikes and political disturbances in some of the copper producing countries curtailed production later in the year whereas demand continued to increase. New records were set in Canada, Chile, Zambia, and the United States. Output from the Congo (Léopoldville) increased slightly but did not attain the plateau of 1959–62. Australia's production was affected adversely by a slowdown at Mount Isa that began in August and resulted in closing all plants later in the year. The slight decrease in production of Peru resulted primarily from milling lower grade ore at Toquepala.

TABLE 43.—World mine production of copper (content of ore) recoverable where indicated, by countries [1] [2]

(Short tons)

Country	1955–59 (average)	1960	1961	1962	1963	1964 [p]
North America:						
Canada [3]	356,069	439,262	439,088	457,385	452,558	494,669
Cuba	16,249	[4] 13,058	[e] 5,500	[e] 6,000	[e] 6,600	[5] 6,600
Haiti	------	1,000	3,832	6,738	6,553	6,208
Mexico	64,398	66,502	54,359	51,945	61,576	57,878
Nicaragua	[6] 1,001	5,398	6,919	8,016	8,028	10,185
United States [3]	998,752	1,080,169	1,165,155	1,228,421	1,213,166	1,246,780
Total	1,436,469	1,605,389	1,674,853	1,758,505	1,748,481	1,822,320
South America:						
Argentina	452	569	607	446	128	379
Bolivia (exports)	3,740	2,503	2,294	2,646	3,300	5,160
Brazil [e]	1,100	1,200	1,900	1,800	1,700	1,700
Chile	534,012	591,330	607,233	653,613	665,951	694,938
Ecuador	49	110	111	174	313	203
Peru	55,171	[3] 200,313	[3] 218,315	[3] 183,854	195,609	192,330
Total	594,524	796,025	830,460	842,533	867,001	894,710
Europe:						
Albania [e]	1,300	2,400	2,600	2,800	2,800	2,800
Austria	2,683	2,188	2,105	2,190	2,078	1,725
Bulgaria [e]	7,900	12,000	19,600	21,500	21,200	21,300
Finland	27,955	31,100	37,500	38,700	37,400	35,600
France [7]	578	619	402	248	302	346
Germany:						
East [e]	20,000	26,500	27,600	28,700	26,500	30,900
West	1,560	1,960	2,393	2,202	2,443	1,726
Ireland	[8] 5,016	6,883	6,534	2,632	------	------
Italy [9]	3,169	3,301	2,658	2,974	[e] 2,700	[e] 2,500
Norway	16,405	16,966	15,379	17,124	15,723	16,327
Poland [e]	8,200	11,600	12,900	15,100	14,600	16,000
Portugal	779	579	622	574	[e] 620	[e] 440
Spain [10]	8,977	8,785	20,029	20,580	26,275	28,698
Sweden	19,034	19,265	20,047	21,044	21,000	22,000
U.S.S.R. [e] [11] [12]	440,000	550,000	600,000	720,000	770,000	770,000
Yugoslavia	36,210	36,682	41,787	57,008	68,447	69,627
Total [e] [11]	600,000	731,000	812,000	953,000	1,012,000	1,020,000

See footnotes at end of table.

TABLE 43.—World mine production of copper (content of ore) recoverable where indicated, by countries [1] [2]—Continued

(Short tons)

Country	1955–59 (average)	1960	1961	1962	1963	1964 [p]
Asia:						
Burma [e]	155	160	125	165	190	140
China [e]	25,000	77,000	88,000	99,000	99,000	99,000
Cyprus (exports)	37,189	39,096	31,586	27,734	29,001	18,514
India	8,885	9,700	9,700	10,913	11,034	11,553
Israel	[6] 4,938	6,151	6,893	6,514	8,510	8,818
Japan	88,167	98,307	106,273	114,221	118,186	116,825
Korea:						
North	4,100	[e] 6,600	[e] 6,600	[e] 8,800	[e] 8,800	[e] 11,000
South	882	454	351	474	678	685
Philippines	39,982	48,513	57,182	60,327	70,602	66,642
Taiwan	1,764	2,315	2,460	2,323	1,785	1,916
Turkey	28,889	30,110	31,793	31,115	28,305	34,924
Total [e] [11]	240,000	318,000	341,000	362,000	376,000	370,000
Africa:						
Algeria	311	152	732	859	1,142	1,204
Angola	1,638	2,113	1,022	1,965	143	--------
Congo (Brazzaville)	--------	--------	176	926	320	--------
Congo (Léopoldville) [12]	274,910	333,225	325,445	327,371	299,097	306,048
Morocco	966	1,389	1,915	2,752	1,991	1,758
South Africa, Republic of	52,026	50,847	57,952	51,115	60.792	65,579
Southern Rhodesia	5,356	15,128	15,243	15,146	18,489	18,341
South-West Africa	29,565	22,597	27,778	24,971	35,774	38,503
Tanzania [13]	1,217	1,404	111	--------	--------	--------
Uganda [12]	[14] 10,115	16,257	14,742	17,173	17,875	20,415
Zambia	472,199	635,326	633,139	619,856	648,239	741,847
Total	848,303	1,078,438	1,078,255	1,062,134	1,083,862	1,193,695
Oceania: Australia	74,319	122,567	107,102	119,809	126,276	116,634
World total [e]	3,790,000	4,650,000	4,840,000	5,100,000	5,210,000	5,420,000

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[e] Estimate.

[p] Preliminary.

[1] Czechoslovakia, Iran, and Hungary also produce copper, but production data are not available. Kenya and Malaya also produce a small amount of copper. No estimates for these countries are included in the total.

[2] This table incorporates some revisions. Data do not add exactly to totals shown because of rounding where estimated figures are included in the detail.

[3] Recoverable.

[4] Exports.

[5] 1963 data.

[6] One year only as 1963 was the first year of commercial production.

[7] Includes copper content of auriferous ores.

[8] Average annual production 1958–59.

[9] Includes copper content of cupriferous pyrites.

[10] According to Yearbook of American Bureau of Metal Statistics. This data does not include content of iron pyrites, the copper content of which may or may not be recovered.

[11] Output from U.S.S.R. in Asia included with U.S.S.R. in Europe.

[12] Smelter production.

[13] Copper content of exports and local sales.

[14] Average annual production 1956–59.

TABLE 44.—World smelter production of copper, by countries [1]

(Short tons)

Country	1955-59 (average)	1960	1961	1962	1963	1964 [p]
North America:						
Canada	327,120	417,029	406,359	382,868	378,911	408,509
Mexico	58,419	64,861	52,498	50,177	60,005	56,234
United States [2]	1,085,374	1,233,629	1,207,354	1,322,614	1,296,700	1,338,433
Total	1,470,913	1,715,519	1,666,211	1,755,659	1,735,616	1,803,176
South America:						
Brazil [3]	1,532	1,336	1,829	2,200	2,200	3,000
Chile	501,111	556,464	578,068	614,235	594,200	645,269
Peru	39,286	181,650	200,699	164,920	173,471	167,624
Total	541,929	739,450	780,596	781,355	769,871	815,893
Europe:						
Albania	981	1,040	1,421	2,050	[e] 2,060	[e] 2,150
Austria [3]	10,748	12,964	13,044	14,186	14,385	16,140
Bulgaria	6,768	17,747	20,834	21,385	22,622	23,259
Finland	29,526	34,140	37,800	37,400	41,664	36,571
Germany:						
East [e]	29,100	35,000	35,000	35,000	37,000	31,000
West [3]	290,301	340,695	335,488	339,778	333,799	370,728
Italy [4]	424	35	------	------	------	------
Norway	18,037	23,825	24,218	21,113	19,734	18,997
Poland	19,993	23,961	24,504	26,608	32,665	40,394
Spain	7,542	9,041	20,029	20,580	26,275	28,186
Sweden	21,898	23,927	22,816	25,100	32,077	24,900
U.S.S.R. [e] [5]	440,000	550,000	600,000	720,000	770,000	770,000
Yugoslavia	35,340	39,384	34,027	50,421	54,048	57,255
Total [e] [5] [6]	911,000	1,112,000	1,169,000	1,314,000	1,386,000	1,420,000
Asia:						
China [e]	32,000	110,000	110,000	110,000	110,000	110,000
India	8,546	9,822	9,189	10,781	10,561	10,444
Japan	123,376	204,494	232,659	233,828	274,515	311,056
Korea:						
North (electrolytic)	3,800	[e] 9,000	[e] 8,800	[e] 11,000	[e] 11,000	[e] 11,000
South	789	1,113	1,456	2,436	2,622	3,097
Taiwan	1.732	1,962	2,500	2,745	1,633	1,769
Turkey	26,572	28,674	22,040	28,412	27,326	28,639
Total [e] [5]	197,000	365,000	387,000	399,000	438,000	476,000
Africa:						
Angola	1,587	1,744	937	877	112	------
Congo (Léopoldville)	274,910	333,225	325,443	327,371	299,097	306,048
South Africa, Republic of	50,846	50,847	57,562	50,905	60,085	60,090
Southern Rhodesia	------	------	12,915	13,599	16,187	16,798
South-West Africa	------	------	------	1,338	22,904	31,428
Uganda	[7] 8,509	16,257	14,742	17,173	17,875	20,415
Zambia	459,381	625,942	627,144	603,783	634,946	708,030
Total	795,233	1,028,015	1,038,743	1,015,046	1,051,206	1,142,809
Oceania: Australia	60,472	79,561	69,997	97,818	99,111	89,067
World total [e]	3,980,000	5,040,000	5,110,000	5,360,000	5,480,000	5,750,000

[e] Estimate.

[p] Preliminary.

[1] This table incorporates some revisions. Data do not add to totals shown because of rounding where estimated figures are included in the detail.

[2] Smelter output from domestic and foreign ores, exclusive of scrap. Production from domestic ores only, exclusive of scrap, was as follows: 1955–59 (average), 999,639 short tons; 1960, 1,142,848; 1961, 1,162,480; 1962, 1,282,126; 1963, 1,258,126; and 1964, 1,301,115.

[3] Includes secondary copper.

[4] In addition Italy produced the following quantities of copper in cement copper in short tons: 1955–59, 5,598; 1960, 5,100; 1961, 5,200; 1962, 4,600; 1963, 3,600; and 1964, not available.

[5] Output from U.S.S.R. in Asia included with U.S.S.R. in Europe.

[6] Belgium reports a large output of refined copper which is believed to be produced principally from crude copper from Congo (Léopoldville); it is not shown here, as that would duplicate output reported under latter country.

[7] Average annual production 1956–59.

NORTH AMERICA

Canada.[3]—Voluntary curtailments made in 1962, and continued in 1963, were suspended and mine production in Canada increased 9 percent to set a new record, thus enabling the Nation to keep a firm hold on fifth place in world output. Production from five new mines also contributed to the rise in output. Increased production was recorded in seven of the nine copper producing provinces, British Columbia and Saskatchewan excepted. Production of refined copper, which had declined for the last 2 years, increased 8 percent and almost equaled that of 1961. Consumption of refined copper rose to a new high. The discovery of a large deposit of zinc-copper-silver ore near Timmins, Ontario, was of major importance and together with high-level demands for copper stimulated active development of known deposits and exploration for new occurrences.

Noranda Mines, Ltd., and Geco Mines, Ltd., were amalgamated December 15, 1964, and the two companies continued under the name Noranda Mines, Ltd.

A rise of 12 percent in the output from Ontario, the leading copper producing province in Canada, resulted from a return to full production at mines and smelters of The International Nickel Company of Canada, Ltd., and increased production at Geco Mines, Ltd. Output decreased, however, at five mines operated by Falconbridge Nickel Mines, Ltd. Late in the year, Texas Gulf Sulphur Co., began removal of some 6 million tons of overburden from the recently discovered massive sulfide body of zinc-copper-silver ore about 11 miles north of Timmins.

The International Nickel Company of Canada, Ltd., Canada's leading producer, raised the rate of production twice during 1964 and produced 16.4 million tons of ore from mines in Ontario and Manitoba. Deliveries of copper totaled 143,200 tons compared with delivery of 126,800 tons in 1963. The Crean Hill mine in the Sudbury District of Ontario began producing early in the year and reached the planned daily production of 3,000 tons during the fourth quarter. The use of cemented sand fill was extended during the year resulting in economies in timber consumption and increased operating efficiency.

Falconbridge Nickel Mines, Ltd., treated 1.9 million tons of ore in 1964 compared with the treatment of 2.1 million tons in 1963. The delivery of 12,500 tons of copper was limited by production because the company had no excess inventory at the beginning of the year.

Geco Mines, Ltd., produced 1.30 million tons of ore from a copper-zinc orebody in Manitouwadge district, Ontario. The concentrate produced contained 25,600 tons of copper and was shipped to the Noranda smelter. McIntyre Porcupine Mines, Ltd., recovered 3,200 tons of copper from 383,000 tons of mill ore.

Rio Algom Mines, Ltd. (R.A.) milled 256,200 tons of ore from the Pater mine. Copper content of concentrate produced was 4,300 tons. North Cold Stream Mines, Ltd., milled 367,000 tons of ore and the concentrate produced contained 7,100 tons of copper. Willroy Mines,

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[3] A substantial part of the information in this section was taken from—Killan, A. F. The Canadian Mineral Industry in 1964, Preliminary. Department of Mines and Technical Surveys, Miner. Res. Div. (Ottawa, Canada), Mineral Information Bulletin MR 79, 1965, pp. 23–27.

Ltd., milled 530,200 tons of ore and the concentrate produced contained 5,300 tons of copper.

The 13-percent increase in production from Quebec was attributed chiefly to the return to full production at the Horne mine of Noranda Mines, Ltd., and a full year's production from three mines at Mattagami. Lake Dufault Mines, Ltd., began treating ore at its mill in the Noranda area in mid-August, and the plant was in full production by October 1. Noranda increased the annual capacity of its smelter from 1.6 million tons of ore and concentrate to 1.75 million tons.

TABLE 45.—Canada; Copper production (mine output), by Provinces

(Short tons)

Province	1955–59 (average)	1960	1961	1962	1963	1964[p]
British Columbia	14,670	16,559	15,845	54,490	62,218	57,506
Manitoba	16,290	12,793	12,454	12,738	16,980	29,192
New Brunswick	1,221	---	---	3,674	8,964	10,522
Newfoundland	8,087	13,863	15,752	17,308	14,012	14,506
Northwest Territories	219	520	463	314	16	652
Nova Scotia	286	---	---	204	237	284
Ontario	160,938	206,272	211,647	188,995	178,960	201,031
Quebec	120,417	157,470	149,007	147,431	141,400	160,288
Saskatchewan	33,941	31,785	33,479	32,017	29,771	20,688
Yukon Territory	---	---	441	214	---	---
Total	356,069	439,262	439,088	457,385	452,558	494,669

[p] Preliminary.

Source: Dominion Bureau of Statistics, Department of Trade and Commerce, Government of Canada, Preliminary Report on Mineral Production, 1964.

Gaspé Copper Mines, Ltd., Canada's second ranking copper producer, mined 2.82 million tons from mines in Quebec. Of the total, 40 percent came from the Needle Mountain open pit mine. The smelter treated 246,000 tons of copper concentrate and fluxing ore, including 51,400 tons of custom concentrate. Anodes produced contained 43,300 tons of copper. Work began to bring the Copper Mountain mine, located about a mile from the Needle Mountain mine, into production by 1968 when crushing and concentrating capacity will have been expanded from 7,500 tons to 11,000 tons per day.

Noranda Mines, Ltd., produced 1.25 million tons of ore, averaging 2.01 percent copper from the Horne mine. Of the total, 897,000 tons was milled and 353,000 tons was smelted directly. A total of 1.64 million tons of ore, concentrate, flux, and scrap, including 670,000 tons of custom material, was smelted. Anodes produced contained 174,800 tons of copper. Output of copper by Canadian Copper Refiners, Ltd., a subsidiary of Noranda, increased from 262,000 tons in 1963 to 270,000 tons as a result of higher production at the Noranda smelter.

Campbell Chibougamau Mines, Ltd., milled 870,000 tons of ore, averaging 1.89 percent copper in fiscal year 1963–64. The Henderson Division supplied 326,000 tons or 37 percent of the total ore produced. The Main Mine Division produced 362,100 tons compared with a production of 202,800 tons in 1962–63. Output from Cedar Bay was 154,000 tons compared with that of 168,500 tons in the previous year. Kokko Creek was placed on a salvage basis, and the ore available for mining was increased by the inclusion of pillars not previously classed as reserve. Production from the mine was 27,800 tons. Concentrate shipments totaled 64,100 tons and contained 15,600 tons of copper.

The concentrator of Quemont Mining Corp., Ltd., produced 46,700 tons of concentrate that contained 8,000 tons of copper, 72,000 ounces of gold, and 264,800 ounces of silver. Normetal Mining Corp., Ltd., milled 348,900 tons of ore averaging 1.89 percent copper and containing zinc and small quantities of gold. The 26,800 tons of copper concentrate produced contained 6,100 tons of copper and was shipped to the Noranda smelter.

Sullico Mines, Ltd., a subsidiary of East Sullivan Mines, Ltd., mined 791,000 tons of ore averaging 0.59 percent copper. Copper production was 5,300 tons. Solbec Copper Mines, Ltd., a subsidiary of Hastings Mining and Development Co., Ltd., treated 368,000 tons of ore averaging 1.80 percent copper. Concentrate produced contained 5,700 tons of copper.

Opemiska Copper Mines (Quebec) Ltd., milled 749,000 tons of ore in 1964 compared with 738,000 tons milled in 1963. The average grade of ore treated was lower, and copper in concentrates was 20,400 tons (20,800 tons in 1963). Copper production by Copper Rand Mines Division, The Patiño Mining Corp., decreased from 16,000 tons to 15,200 tons despite the treatment of 674,000 tons of ore compared with that of 624,500 tons in 1963. The lower output resulted from milling ore of lower copper content.

The daily milling rate of the concentrator of Mattagami Lake Mines, Ltd., rose from 3,200 tons to 3,850 tons. Zinc-copper ore processed totaled 1.3 million tons from which 36,000 tons of copper concentrate averaging 18.19 percent copper was produced. The concentrate was shipped to the smelter at Noranda. Orchan Mines, Ltd., milled 369,300 tons of zinc-copper ore from which 18,900 tons of copper concentrate was recovered. The concentrate contained 3,200 tons of copper. During the year ending August 31, 1964, New Hosco Mines, Ltd., trucked 263,000 tons of ore with an average grade of 2.13 percent copper to the concentrator of Orchan Mines, Ltd. Mixed concentrate shipments to the smelter at Noranda contained 4,800 tons of copper for New Hosco account.

A large increase in production from Manitoba more than offset the drop in output from Saskatchewan, and the combined production from the two provinces increased 7 percent.

Hudson Bay Mining and Smelting Co., Ltd., milled 1.6 million tons of ore, 33,000 tons less than that milled in 1963, from mines in Manitoba and Saskatchewan. The grade of the ore treated, however, increased from an average of 2.58 percent copper in 1963 to 2.83 percent in 1964. Of the ore treated, the Flin Flon mine supplied 50 percent, Chisel Lake 17 percent, Stall Lake, which was brought into production early in February, 17 percent, Coronation 12 percent, Schist Lake 4 percent; less than 1 percent of the ore treated was purchased. The smelter treated 396,300 tons of Hudson Bay concentrate, direct smelting ore and residue; also 15,500 tons of custom materials were treated. Blister copper output totaled 41,100 tons, and 40,400 tons of refined copper was produced.

Sherritt Gordon Mines, Ltd., milled 1.4 million tons of nickel-copper ore at the concentrator at Lynn Lake. Concentrate produced contained 6,500 tons of copper compared with that of 6,000 tons in 1963.

A decrease in production from British Columbia was attributed to the closing of two mines and five other mines reaching their rated capacities in 1963. The Jordan River mine of Cowichan Copper Co., Ltd., was closed throughout the year as a result of flooding in December 1963 when a stope broke through to the surface under the Jordan River. A strike on August 1 closed the Britannia mine of The Anaconda Company (Canada), Ltd., and the mine did not resume operations during the remainder of the year.

During the fiscal year ended October 31, 1964, Craigmont Mines, Ltd., the largest producer of copper in British Columbia, milled 1.9 million tons of ore averaging 1.63 percent copper. Concentrate produced contained 29,000 tons of copper. The Phoenix Copper Co., Ltd., Division of the Granby Mining Company, Ltd., treated 686,000 tons of ore averaging 0.71 percent copper. Saleable copper produced totaled 3,800 tons compared with that of 3,400 tons in 1963. The stripping ratio increased from 3.48 tons of waste to 1 of ore in 1963 to 3.88 tons to 1.

Bethlehem Copper Corp., Ltd., milled 1.4 million tons of ore (1.3 million tons in 1963) averaging 0.89 (1.06) percent copper during the fiscal year ended February 28, 1965. Copper content of concentrate shipped to Japan was 11,900 tons. A target date was set for March 1, 1965, for increasing the daily capacity to 10,000 tons. Coast Copper Co., Ltd., a subsidiary of Consolidated Mining and Smelting Company of Canada, Ltd., produced 306,000 tons of copper ore, which was treated at the mill of the latter company. Concentrate produced was shipped to Japan.

Brunswick Mining and Smelting Corporation, Ltd., became New Brunswick's newest producer when the concentrator began operating in March. Throughput of the mill, which is about 10 miles south of Bathurst, was increased from 3,000 tons per day to 4,500 tons by July 1.

Heath Steele Mines, Ltd., continued operation of its 1,500-ton-per-day mill, treating ore from its mine and from the Wedge mine of the Consolidated Mining and Smelting Company of Canada, Ltd. (Cominco). The latter mine produced 282,000 tons of ore and 39,000 tons of concentrate which was shipped to Japan.

In Newfoundland, production from three established producers and a new mine increased output from the province 4 percent. The 500-ton-per-day concentrator of Consolidated Rambler Mines, Ltd., began production in October and reached its rated capacity in November. The Rambler property was developed by a three-compartment shaft to 935 feet below the collar and lateral workings on four levels. Exploration of a new ore body, about 1 mile from the shaft, indicated more than 2 million tons of ore, averaging 1.6 percent copper.

Atlantic Coast Copper Corp., Ltd., milled 318,000 tons of ore yielding 2,700 tons of copper. The remainder of the copper produced in the province came from Tilt Cove mine of First Maritime Mining Corp., Ltd., and American Smelting and Refining Company's Mc-

Lean mine. First Maritime Mining Corp., Ltd., formerly Maritimes Mining Corp., Ltd., continued to prepare the Gull Pond mine of Gullbridge Mines, Ltd., for production with a target set for output to begin by mid-1965.

Production of refined copper in Canada, which declined in 1962 and 1963, rose to 408,500 tons, 29,600 tons more than production in 1963. Consumption of refined copper rose to 202,200 tons, 19 percent more than the previous high set in 1963.

Exports of copper in ore, concentrate, and matte reached a record high of 104,600 tons, 13 percent more than exports in 1963. Of the total, 65,200 tons (57,300 tons in 1963) went to Japan, 13,200 tons (15,700) to the United States, and 12,400 tons (15,300) to Norway. Sweden returned to the list of nations importing copper from Canada and received 7,200 tons. West Germany imported 2,500 tons (948), Belgium-Luxembourg 2,000 tons (1,000), and the United Kingdom 1,600 tons (1,800). France and Mexico received the remainder. Exports of ingots, bars, and billets were as follows:

Destination:	Short tons *1963*	Short tons *1964*
United Kingdom	98, 703	110, 396
United States	74, 098	85, 293
France	6, 112	15, 666
Germany, West	7, 013	2, 907
Sweden	3, 695	2, 303
Belgium-Luxembourg	2, 255	1, 835
Italy	1, 829	1, 735
Switzerland	-----	1, 373
Poland	3, 807	952
India	13, 834	421
Other countries	3, 641	1, 392
Total	214, 987	224, 273

In addition, 43,900 tons (33,900 tons in 1963) of rods, strips, sheet, tubing, and other shapes was exported, of which 8,900 tons went to the United States, 6,700 tons to Norway, 6,200 tons to Switzerland, and 3,800 tons to each Pakistan and the United Kingdom. New Zealand received 2,900 tons, whereas Denmark, Spain, and Venezuela each received about 2,000 tons.

Mexico.—Compañia Minera de Cananea, S.A. de C.V. produced 32,100 tons of blister copper, that was shipped to Cobre de Mexico S.A., Mexico City, for refining. Underground mining was curtailed and operations were concentrated on open pit mining. Construction began on a new crushing and conveying system that, when completed early in 1966, will eliminate truck-haulage from the pit to the concentrator. Concentrator circuits were being modified to treat an increase in mine production of about 37 percent.

SOUTH AMERICA

Chile.—Despite strikes and other labor difficulties, mine production of copper reached a record high of 694,900 tons, a 4 percent increase over 1963.

The Chuquicamata mine of Chile Exploration Co., a subsidiary of The Anaconda Company, produced 317,500 tons, a record for this mine. A daily average of 188,000 tons of ore and waste was transported from the mine. Modifications in the concentrator increased milling capacity to about 55,000 tons per day and improved recovery of copper. Andes Copper Mining Co., another Anaconda subsidiary, produced 84,300 tons of copper from its El Salvador mine. Material handling methods were modernized at the smelter at Potrerillos. The electrolytic refinery began operating in December. Work was nearing completion on other facilities at the refinery. When in full operation the refinery at Potrerillos will have an annual capacity of about 36,000 tons. La Africana mine of Santiago Mining Co., another subsidiary of Anaconda, produced 28,500 tons of concentrate, having a copper content of 26.97 percent compared with a production of 27,700 tons of concentrate with a copper content of 27.45 percent in 1963.

The Braden Copper Co., a subsidiary of Kennecott Copper Corp., mined and milled 11.5 million tons of ore from the El Teniente mine, compared with that of 9.5 million tons in 1963. The average grade of the ore treated decreased from 1.94 percent copper to 1.88 percent. Production of copper totaled 184,700 tons, compared with that of 154,900 tons in 1963.

The newly completed Las Ventanas copper smelter, built by Chilean National Mining Enterprise (ENAMI), began a 6-month testing period in August. The smelter, on Quintero Bay about 16 miles north of Valparaiso, will have an annual yield of 30,000 tons of copper.

Soon after the election and inauguration of a new president late in 1964, three large U.S. companies and representatives of the Chilean Government began negotiation for the expansion of production from existing mines and development of new deposits.[4] Agreements were reached between the Government and the companies relative to government participation in the activities of the companies and stabilization of taxes. Legislation enabling the Government to enter into the agreements was introduced into the Congress of Chile and action thereon was pending at yearend.

West Germany, by receipts of 14,000 tons of a total of 39,300 tons of copper exported in ore and concentrate, replaced Japan, 11,700 tons received, as the leading importer of this class of material from Chile. Other countries importing copper in ore and concentrate were Sweden, 4,800 tons; Spain, 3,100 tons; Belgium, 2,800 tons; Poland, 1,500 tons; Peru and the United States, 700 tons each.

Peru.—Operations of the Cerro de Pasco Corp. (Cerro-Peru) were uninterrupted and a new production record of 41,700 tons of copper was established. Construction of a new copper precipitation plant began at Cerro de Pasco to recover 8,000 tons of precipitate copper annually from mine water and leach dumps. Planned output will be nearly twice the present production of precipitate copper. Construction of a 750-ton-per-day concentrator was included in plans to convert the Yauricocha mine from producing direct smelting copper ore to mill zinc-lead-copper-silver ore. It was expected that the project will be completed in 1966.

Southern Peru Copper Corp. produced 11.1 million tons of ore averaging 1.34 percent copper. Blister copper output was 127,500 tons compared with that of 131,000 tons in 1963. The decrease in output was attributed to a slight decrease in grade of ore and a modest reduction in ore production caused by three strikes that totaled 13 days lost time at the mine and smelter.

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[4] The Anaconda Company, Cerro Corporation, and Kennecott Copper Corp. Annual Reports, 1964

TABLE 46.—Chile: Exports of copper, by principal types

(Short tons)

Destination	1963 [r]				1964			
	Refined		Blister	Total	Refined		Blister	Total
	Electrolytic	Fire refined			Electrolytic	Fire refined		
Argentina	6,326	1,377	----------	7,703	6,413	6,960	----------	13,373
Belgium	111	2,353	7,376	9,840	----------	390	15,818	16,208
Brazil	24,694	7,631	11	32,336	17,162	6,716	----------	23,878
Finland	----------	----------	----------	----------	1,926	----------	----------	1,926
France	8,028	5,708	----------	13,736	12,501	7,409	----------	19,910
Germany, West	24,006	10,422	41,824	76,252	13,920	11,066	38,573	63,559
Italy	19,703	15,311	111	35,125	14,160	9,910	----------	24,070
Netherlands	40,093	1,510	----------	41,603	32,739	1,083	----------	33,822
Sweden	28,378	1,566	2,004	31,948	21,646	1,040	2,828	25,514
United Kingdom	32,758	38,341	42,924	114,023	24,106	34,317	43,442	101,865
United States	1,898	----------	230,935	232,833	11,246	----------	240,700	251,946
Other countries	110	270	----------	380	----------	502	----------	502
Total	186,105	84,489	325,185	595,779	155,819	79,393	341,361	576,573

[r] Revised.

EUROPE

Finland.—Although ore produced from mines of Outokumpu Oy increased from 2.7 million tons in 1963 to 2.8 million tons in 1964, a decrease in copper output from Outokumpu, the largest producer, more than offset small increases from other mines. Copper production was as follows:

Mine	Ore (short tons)	Copper concentrate (short tons)	Copper (short tons)
Outokumpu	662,900	104,600	24,300
Ylojarvi	335,000	10,300	2,100
Vihanti	514,600	11,500	3,000
Kotalahti	507,300	4,300	1,100
Pyhasalmi	680,700	31,500	5,000
Metsämonttu	56,400	200	50
Total	2,756,900	162,400	35,550

The Pori refinery produced 36,600 tons of cathodes.

United Kingdom.—The free world's second largest copper-consuming country, the United Kingdom consumed a total of 697,600 tons of primary and secondary copper compared with a consumption of 615,000 tons in 1963.[5] In addition, 171,700 tons (151,500 tons in 1963) of copper in scrap was used. Output of semimanufactured products consumed 676,900 tons of refined copper and 104,900 tons of scrap;

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[5] British Bureau of Nonferrous Metal Statistics. World Non-Ferrous Metal Statistics. V. 18, No. 3, March 1965, pp. 9, 10, 13.

whereas castings, manufacture of copper sulfate, and miscellaneous products used 20,700 tons of refined copper and 66,800 tons of scrap. Production of copper sulfate was 29,100 tons (25,300 tons in 1963).

TABLE 47.—United Kingdom: Imports of copper, by countries

(Short tons)

Source	1963			1964		
	Blister	Electrolytic	Fire refined	Blister	Electrolytic	Fire refined
Zambia	55, 396	193, 813	113	55, 450	209, 755	1, 133
Canada	----	106, 117	----	----	109, 865	----
Chile	41, 831	30, 000	38, 760	46, 311	26, 867	35, 060
United States	----	31, 816	657	----	49, 358	1, 809
Peru	14, 118	16, 505	----	8, 797	562	----
South Africa, Republic of	112	----	1, 400	336	84	8, 639
Germany:						
West	----	755	4, 502	----	8, 096	590
East	----	----	----	----	896	----
Belgium	----	2, 392	----	----	5, 992	----
Australia	----	5, 720	----	----	5, 895	----
Congo (Léopoldville)	----	3, 276	----	----	3, 416	----
Netherlands	----	----	----	----	1, 784	140
U.S.S.R	----	----	----	----	706	----
Norway	----	952	----	----	610	----
Italy	----	----	----	----	279	----
Spain	----	3, 453	----	----	22	----
Other countries	----	315	----	61	753	28
Total	111, 457	395, 114	45, 432	110, 955	424, 940	47, 399

Source: British Bureau of Nonferrous Metal Statistics.

Exports and reexports of refined copper continued to drop and totaled 39,900 tons, 38 percent less than shipments in 1963 and 71 percent less than those in 1962.

TABLE 48.—United Kingdom: Exports and reexports, by countries

(Short tons)

Destination	1963	1964	Destination	1963	1964
Netherlands	4, 724	10, 203	Australia	12	741
Germany:			Italy	190	594
West	4, 311	8, 029	Norway	869	561
East	2, 333	----	Czechoslovakia	560	560
Argentina	945	3, 710	India	211	521
China	1, 182	2, 690	Poland	1, 792	56
Sweden	1, 285	2, 658	Belgium	34, 060	50
United Arab Republic (Egypt)	4, 420	1, 915	U.S.S.R	1, 120	----
France	18	1, 748	Finland	890	----
United States	30	1, 709	Other countries	5, 312	2, 428
Yugoslavia	----	1, 697			
			Total	64, 264	39, 870

Source: British Bureau of Nonferrous Metal Statistics.

Yugoslavia.—Mine production in 1964 totaled 6.5 million tons of ore with grades between 0.3 and 2.8 percent. Smelter output was 57,300 tons (54,000 tons in 1963).

ASIA

Cyprus.—Mining and milling operations of Cyprus Mines Corp. were interrupted until mid-April by political unrest. During this period, however, stripping continued at the Skouriotissa mine and shipments of copper concentrate were made from a limited stockpile. Shipments in 1964 consisted of 42,200 tons of copper concentrate, 43,700 tons of cupreous pyrite, and 3,200 tons of copper precipitate. In addition, 468,700 tons of pyrite concentrate was produced by flotation. The Skouriotissa mine had its first year of operation, and the Apliki mine was being developed for production in 1965.

India.—Production of copper ore was 522,000 tons averaging 2.22 percent copper. The entire output of copper of about 10,000 tons came from the Mosaboni mine of the Indian Copper Corp. Milling and smelting equipment at the mine, which is in the Singhbhum district of Bihar, were reported to be old and inefficient.

The copper project at Khetri in Rajasthan, planned for the recovery of 21,000 tons of copper, was delayed by lack of funds.[6] An application for about $20 million, the foreign exchange cost of the project was submitted to the United States Agency for International Development (USAID).

Israel.—Copper contained in cement copper produced from treating 540,000 tons of ore increased 28 percent over output in 1963. The ore averaged about 2 percent and the cement copper between 70 and 80 percent.

Japan.—Approximately 13.5 million tons of ore that contained 125,900 tons of copper was mined in 1964. Output of concentrate totaled 603,400 tons of concentrate containing 116,500 tons of copper. Production of electrolytic copper totaled 506,800 tons, of which 376,600 tons and 130,200 tons were derived from primary and secondary materials, respectively.

Philippines.—Output of copper in ore and concentrate totaled 66,700 tons, 3,500 tons less than that in 1963. As a result of a series of slides, Atlas Consolidated Mining & Development Corp. ceased operating the Lutopan mine as an open pit operation and completed sinking a shaft and developing two levels for underground mining. Copper content in concentrate produced totaled 27,700 tons compared with that of 31,300 tons in 1963.

Marinduque Mining and Industrial Corp. produced 15,500 tons of copper from its Baqacay and Sipalay projects.

Lepanto Consolidated Mining Co., Ltd., milled 477,500 tons of ore in 1964 compared with 463,500 tons milled in 1963, but the average grade was 2.91 percent copper compared with an average of 3.04 percent in the previous year. The result was that copper contained in concentrate produced decreased 2 percent to 13,200 tons.

Relatively small outputs of copper were reported by Philex Mining Corp.; Samar Mining Co., Inc.; Surigao Consolidated Mining Co., Inc.; and Copper Belt Mining Co.; the latter of which began production during 1964.

Turkey.—Output of blister copper increased 4 percent in 1964. Ore production totaled 895,000 tons, of which 326,800 tons averaging 6.07

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[6] Bureau of Mines. Mineral Trade Notes. V. 60, No. 1, January 1965, pp. 10–11.

percent copper was mined and milled at Ergani, and 558 tons averaging 2.01 percent copper was produced and processed at the Murgul mine. In addition, 9,300 tons of 10.00 percent ore was hand sorted at Küre and exported for treatment. Blister copper production from concentrates produced at Ergani and Murgul was 20,000 tons and 8,600 tons, respectively.

AFRICA

Congo (Léopoldville), Republic of the.—Coincident with the return of stability to the Katanga region, operations of the Union Minière du Haut Katanga were not seriously interrupted, and production increased 2 percent. Open pit mining, however, continued to be affected unfavorably by a shortage of skilled labor required for operating and maintaining heavy equipment. Rescheduling of shipments was required as a result of disruptions of traffic by adverse weather, strife, and military operations in other parts of the Nation, and a railroad strike in Southern Rhodesia.

Ore production increased to 7.2 million tons, and in addition, large quantities of stockpiled ore were treated as in the previous year. The Western Group produced 4.7 million tons of ore; Musonoi 2.5, Kamoto open pit mine 1.4, Ruwe .7; and the Kingamyambo open pit mine, that worked for 3 months 121,000 tons. Development at the Kamoto underground mine supplied 16,000 tons. Production increased from the Kipushi mine in the Southern Group and totaled 1.1 million tons. Flexible metal floors composed of interlacing strips replaced timbering in stopes where top-slicing methods were used. In the Central Group the Kambove-West open pit produced 633,000 tons, Kambove-West underground mine 110,000 tons by top slicing, and the Kakanda mine 670,000 tons.

The Kolwezi concentrator treated 4.4 million tons of ore, of which 3.6 million tons was siliceous oxide ore, mainly from Kamoto, Musonoi, and stockpiles, together with 811,000 tons of mixed oxide and sulfide ore supplied chiefly by Musonoi. Concentrate production was 706,600 tons, averaging 25.28 percent copper from oxide ore and 86,400 tons averaging 30.26 percent copper from mixed ores. During the year the Kipushi concentrator treated 1.1 million tons from the Kipushi mine by differential flotation and produced 205,500 tons of 27.56 percent copper concentrate, and 197,200 tons of 59.00 zinc concentrate. The Kambove concentrator processed 949,000 tons of ore from the Kambove open pit and underground mines and from stockpiles previously built. Production totaled 152,300 tons of concentrate averaging 27.21 percent copper and 1.60 percent cobalt. The washing plant treated 161,000 tons of talcose ore taken from stockpiles and recovered 102,000 tons of material averaging 6.69 percent copper that was fed to the Kambove concentrator. Output from the Kakanda concentrator was 86,400 tons of 23.70 percent copper concentrate derived from 697,000 tons of oxide ore from the Kakanda mine and a small quantity from stockpiles. The feed of the Ruwe washery was composed of 705,000 tons of breccia and 512,000 tons of material from stocks. Production was 38,300 tons of concentrate containing 24.63 percent copper and 270,600 tons of product containing 6.92 percent copper for reprocessing at the concentrator.

The Lubumbashi plants (Elisabethsville) produced blister copper for 9 months and crude copper for soluable anodes at Shituru during January, August, and December. Overhauling generators at the Shituru (Jadotville) plants resulted in a 15 percent reduction in the capacity of the electrolysis section. The Luilu plants (Kolwezi) worked at their normal capacity throughout the year. Total output for the year was as follows:

	Short tons
Electrolytic copper ingot	154, 571
Cathodes	79, 283
Crude copper (blister and other types)	69, 793
Copper in various products	91
Total	303, 738

Malawi, Southern Rhodesia, and Zambia.—The independent nation, Zambia, created on October 24, 1964, occupies the area that was formerly Northern Rhodesia. The British South Africa Co. yielded its mineral rights in Zambia a few hours before the change in sovereignty. The company was reported to have received £2 million (about $5.6 million) from each the British and Zambian Governments. The company had received royalties on copper produced in Northern Rhodesia under mineral rights dating back to 1889.

Operations at mines and plants in Zambia were not seriously affected by stoppages, and record outputs were reached. Mine production rose 8 percent, smelter output 10 percent, and refinery output 13 percent.

In the fiscal year ended June 30, 1964, Roan Antelope Division of Rhodesian Selection Trust, Ltd. (RST Group), produced 6.47 million tons of ore averaging 1.73 percent total copper and 0.16 percent oxide copper. Roan Extension provided 70 percent of the ore and the remainder came from Roan Basin. Smelter output totaled 104,100 tons, of which 7,300 tons was fire refinable grade and the remainder was sent to the Ndola plant for electrolytic refining.

During the same period, Chibuluma Mines, Ltd., mined 670,000 tons of ore averaging 4.29 percent copper and 0.13 percent oxide copper. Mine production throughout the year was from Chibuluma and Chibuluma West. Copper concentrate production totaling 82,645 tons was treated at smelters within the RST Group. Output of copper from the concentrate was 26,400 tons of fire refinable grade, an increase of 4,000 tons over that of fiscal year 1963.

Mufulira Copper Mines, Ltd., produced 7.55 million tons of ore averaging 2.66 percent copper and 0.07 percent oxide copper in fiscal year ended June 30, 1964. All stoping was above the 1900 level, and ore production in 1963–64 was produced as follows: Block caving 54.4 percent, open stoping 38.1 percent, and development 7.5 percent. Anode copper produced totaled 175,900 tons compared with that of 125,200 tons in fiscal year 1963. Approximately 75 percent of the year's output was sent to the refinery and 133,685 tons of electrolytic copper was produced.

Ndola Copper Refineries, Ltd., produced 117,800 tons of refined copper of which 97.8 percent was for associated companies of the RST Group. This compares with production of 100,300 tons and 88.5 percent in fiscal year 1963.

During the year ended June 20, 1964, 5.91 million cubic yards of overburden and 614,000 tons of oxide ore were removed from the Chambishi mine. Delayed deliveries of materials and equipment affected construction of a plant to recover copper from oxide ore, some production from the plant, however, is expected in 1964–65.

Late in 1964, the name of Rhodesian Selection Trust, Ltd., was changed to Roan Selection Trust, Ltd., as a result of the constitutional change in the Federation of Rhodesia and Nyasaland, whereby the name Rhodesia would apply to Southern Rhodesia only. Roan Antelope Division of Rhodesian Selection Trust, Ltd., was named Luanshya Division of RST.

Nchanga Consolidated Copper Mines, Ltd., mined 5.3 million tons of ore averaging 5.24 percent copper during the year ended March 31, 1964. Nchanga mine, including the upper ore body supplied 3.5 million tons, Nchanga open pit 1.3 million, and Chingola open pit 0.5 million. Output of copper established a production record of 233,900 tons—36,800 tons of blister and 197,100 tons of electrolytic copper. Arrangements were made during 1964 for increased mine production from Nchanga to be treated by excess concentrating capacity at Bancroft. The second stage of the low-grade oxide leaching plant began operations in June 1964. Provisions were made at the plant for roasting and treating low-grade sulfide concentrate, thus enabling the smelter at Nkana to increase its capacity for high-grade concentrate.

Rhokana Corporation, Ltd., mined and milled 5.6 million tons of ore in the fiscal year ended June 30, 1964. Concentrate production was 319,600 tons averaging 36.04 percent copper and 1.05 percent cobalt. Development of an open pit began in the predominantly oxide zone north of Mindola. Construction began on a commercial-scale TORCO plant (treatment of refractory copper ores), that was planned to treat ore from the new open pit mine. The smelter produced 296,500 tons of anode and blister copper, compared with a production of 284,900 tons in fiscal year 1963. An increase in production of blister for Rhokana and Nchanga more than offset a reduction for Bancroft, whereas there was a net decrease in the output of anodes, although a substantial quantity of anodes was produced for the first time from materials from Bancroft. Of the total, 34,900 tons of blister (12,000 tons in 1963) and 78,300 tons of anodes (95,500 tons in 1963) were recovered from materials from Rhokana, 47,500 tons of blister (14,300 tons in 1963) and 97,300 tons of anodes (114,800 tons in 1963) for Nchanga, and 11,200 tons of blister (48,300 tons in 1963) and 27,300 tons of anodes for Bancroft.

Arrangements were made for most of the output of Bancroft Mines, Ltd., to be in the form of electrolytic copper after July 1, 1963. Production for the year ending June 30, 1964, was 25,400 tons of electrolytic copper and 11,200 tons of blister copper, compared with 48,300 tons of blister copper in 1962–63. In July-August 1964, Nchanga Consolidated Copper Mines, Ltd., made an offer to holders of Bancroft ordinary stock for an exchange of stock. Bancroft became a subsidiary of Nchanga as a result of acceptance of the offer by a large percentage of stockholders. The offer included provision for processing ore from Nchanga at Bancroft and for Nchanga to finance

Bancroft's requirements for increased development to support an annual production of approximately 67,000 tons of copper.

Output of refined copper by Rhodesia Copper Refineries, Ltd., totaled 293,600 tons in fiscal year ended June 30, 1964, compared with that of 257,000 tons in fiscal year 1963. Production of cathodes decreased from 25,000 tons to 19,400 tons, but output of wire bars and other electrolytic shapes rose from 232,000 tons to 274,000 tons.

Production of copper in Southern Rhodesia declined slightly from that of 1963. Practically all the production came from three mines of Messina (Transvaal) Development Company, Ltd., and its subsidiary M.T.D. (Mangula) Ltd. In fiscal year ended September 30, 1964, 98,000 tons of ore and tailing averaging 2.19 percent copper was processed in the concentrator at Umkondo. Concentrate produced contained 1,800 tons of copper. At Alaska, concentrate produced from milling 259,000 tons of ore contained 3,500 tons of copper. The ore averaging 2.04 percent copper was derived from open pit mining and development work performed to change from open pit to underground mining. At Mangula 1.22 million tons of ore, averaging 1.17 percent copper, yielded 13,400 tons of copper in concentrate. Output of the Alaska smelter of Messina Rhodesia Smelting and Refining Co., Ltd., was 15,800 tons, an increase of 18 percent over that of fiscal year 1963.

South Africa, Republic of.—Production of copper by O'okiep Copper Co., Ltd., from mines near Springbok in Namaqualand was the highest in the history of the company. A total of 2.6 million tons of ore averaging 1.93 percent copper was mined and milled during fiscal year ended June 30, 1964. In October, the production rate at Carolusberg was increased from 80,000 to 100,000 tons per month. By yearend, ore was being mined from the newly developed lower East O'okiep deposit, whereas operations were terminated at the West O'okiep and Naraap mines because of exhaustion of ore reserves.

In Northern Transvaal, Messina (Transvaal) Development Co., Ltd., milled 1 million tons of ore averaging 1.38 percent copper in the fiscal year that ended September 30, 1964. The concentrate produced contained 13,000 tons of copper, 1 percent more than in 1963.

Construction of the $104 million production facilities at the copper deposit of Palabora Mining Company, Ltd., in North Eastern Transvaal continued on schedule and operations were expected to begin in the first half of 1966. The project was enlarged to include construction of a sulfuric acid plant to produce 300 tons of sulfuric acid per day from converted gases.

South-West Africa.—The increase in the production of copper in South-West Africa was attributed to an increase in quantity and grade of ore produced from the mines of Tsumeb Corp., Ltd. In fiscal year ended June 30, 1964, a total of 1.02 million tons of complex ore averaging 4.02 percent copper was milled. Blister copper output from the modern integrated lead-and-copper smelter was 27,100 tons. Annual installed blister copper capacity of the smelter is 36,000 tons.[7]

Uganda.—Kilembe Mines, Ltd., treated 997,000 tons of ore of which 7,700 tons was direct smelting ore. The grade of mill ore increased slightly, and improvements were made in the grade of concentrate produced and percentage of recovery of copper as a result of treating sulfide ore only. After February, all ore was mined by underground methods. Blister copper production was 20,100 tons, 13 percent more than that in 1963.

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[7] Tsumeb Corp., Ltd. Smelter Plants—General Information. March 3, 1964, 12 pp.

OCEANIA

Australia.—Output of copper from Australia was affected adversely by labor unrest at Mount Isa Mines, Ltd. A work slowdown began in August, the copper smelter closed November 14, and all operations ceased December 15. The Government of Australia placed an emergency ban, effective November 21, on exports of copper and scrap in an attempt to alleviate a short supply in Australia. Concentrate and semimanufacturers, however, remained exportable.

Mount Isa Mines, Ltd., Queensland, a subsidary of American Smelting and Refining Company, treated a record 3.0 million tons of copper ore in the year ended June 30, 1964. In addition, 0.3 million tons of ore from the open-cut mine was stockpiled for future treatment. Refined copper production was 75,500 tons, and concentrates exported to Japan contained an additional 2,200 tons of copper. Copper Refineries Pty., Ltd., produced 75,500 tons of refined copper, of which 44,000 tons was wire bars; 5,300 tons, cathode; 14,500 tons, cakes and billets; and 11,700 tons, rod and wire. Emphasis was placed on increasing the production of semicontinuously cast cakes and billets.

In fiscal year ended June 28, 1964, Mount Morgan, Ltd., milled a record tonnage of 1.42 million tons of ore and removed 3.13 million tons of overburden. The copper grade of the ore treated was fractionally lower than that in 1963, but copper in the concentrate totaled 9,000 tons (8,300 tons in 1963). Blister copper produced was 9,000 tons compared with a production of 8,000 tons in the preceding year. The company entered an agreement with Sumitomo Metal Mining Co., Ltd. The Japanese company will receive the entire production or about 8,000 tons annually of the Australian company's smelter for 10 years. Shipments to Sumitomo's Niihama refinery will begin in 1965.

The Mount Lyell Mining and Railway Co., Ltd., Tasmania, mined 2.4 million tons of ore from open pit and underground mines in fiscal year ended June 30, 1964. As a result of treating lower-grade ore, recoverable copper in concentrate decreased from 15,800 tons to 14,800 tons. Blister copper production was 16,900 tons (14,900 tons in 1963), and output of electrolytic copper was 13,200 tons (13,100 tons in 1963).

TECHNOLOGY

The Bureau of Mines published a comprehensive report that discussed marketing copper ore.[8] Another publication described the results of investigations pertaining to the chemistry involved in the dissolution of iron and copper from sulfide minerals.[9] Chemical criteria used to evaluate activity of microorganisms on the minerals were changes in pH, ferric iron produced, and oxygen consumption. Results obtained in a study of the technical feasibility of recovering a usable pig iron from typical copper reverberatory slags were published.[10] Iron in the slag was readily reduced with carbon, but the sulfur and copper content of the metal was best controlled by melting the slag with pyrite to remove the copper as a low-grade matte, smelting the decopperized slag to reduce the iron, and refining the iron alloy.

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[8] Salsbury, Melford H., W. H. Kerns, F. B. Faulkerson, and G. C. Banner. Marketing Ores and Concentrates of Gold, Silver, Copper, Lead, and Zinc. BuMines Inf. Circ. 8206, 1964, 150 pp.

[9] Sutton, Joseph A., and J. D. Corrick. Leaching Copper Sulfide Minerals With Selected Autotrophic Bacteria. BuMines Rept. of Inv. 6423, 1964, 23 pp.

Another publication described the results of laboratory research which demonstrated that high-grade copper powders can be produced under controlled conditions from cement copper products.[11] A continuous drum-type precipitator was the preferred unit for producing particles of cement copper that were further processed and ground to a powder. Information was published on thermodynamic properties of two salts of copper.[12]

The Calumet Division of Calumet and Hecla, Inc., increased the ratio of discovery of ore in the footwall of the Osceola amygdaloid lode in the native copper district of the Upper Peninsula of Michigan by probing exploratory drill holes by induced polarization methods.[13] Apparatus developed for probing consisted of a semirigid, polyethylene coiled probe and a power supply-instrument case that was easily transported by one man. The use of the probe also provided information on the configuration of the footwall contact for the orientation of development workings and exclusion of barren pockets from development plans.

Application of geologic knowledge to control grade resulted in an increase of about 1.8 pounds of copper per ton of ore mined at the White Pine mine in Michigan.[14] The mine is situated on the crest of a gently plunging anticline. Copper concentrations occur in beds of varying thickness and area distribution. Isograde maps were constructed on mylar film from data obtained in core drilling the deposit on a 1,000-foot-square grid pattern. The location of each working face was plotted on a plan of the mine workings and was compared with isograde maps of each bed to determine the copper in the beds.

A new mapping and ore body evaluation technique used a computer for interpolating random field data.[15] The computer produced contour maps that represented grade of ore, net recovered dollar value, volume of ore, and other parameters for planning purposes.

All mining activity at the Ray Mines Division of Kennecott Copper Corp. was monitored by a radio-television network that was considered to be an indispensable tool for operational control.[16] The many advantages of the circuits included immediate appraisal of equipment breakdowns, quick reporting of unsafe working conditions or accidents, and more efficient dispatching of haulage equipment.

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[10] Edlund, V. E. Smelting Copper Reverberatory Slags To Recover Iron of Low Copper and Sulfur Content. BuMines Rept. of Inv. 6481, 1964, 13 pp.

[11] Groves, R. D. Preparation of Copper Powder From Leach Solutions After Precipitation with Iron. BuMines Rept. of Inv. 6486, 1964, 23 pp.

[12] Barany, R., L. B. Pankratz, and W. W. Weller. Thermodynamic Properties of Cuprous and Cupric Ferrites. BuMines Rept. of Inv. 6513, 1964, 19 pp.

[13] Schillinger, A. W. The Application of Induced Polarization Probing Techniques Underground; Michigan Copper District. Trans. Soc. Min. Eng. (AIME), v. 229, December 1964, pp. 409–415.

[14] Ensign, Chester O. Ore Dilution Control Increases Earnings at White Pine. Min. Eng., v. 16, No. 4, April 1964, pp. 73–80.

[15] Surkau, A. J., J. R. Denny, and J. Batcha. Computer Contouring; New Tool for Evaluation and Analysis of Mines. E&MJ, v. 165, No. 12, December 1964, pp. 72–76.

[16] Bogert, John C. Electronic Eyes and Ears Monitor Pit Operations. Metal Min. and Proc., v. 1, No. 3, March 1964, pp. 42–45.

Open pit mining operations and concentrating practices at the Bethlehem Copper Corp., Ltd., Highland Valley, British Columbia, were described.[17]

An article described mechanized sublevel caving and metallurgical processes at Mount Isa, Queensland, Australia; other mining operations in Oceania were described briefly.[18]

A maximum inflow of 110,000 gallons of water per minute was encountered in driving twin tunnels to drain and ventilate the Casapalca mine on the western slope of the Andes mountains in Peru.[19] The objective of the tunnels was to drain and ventilate a section of the mine where temperatures of 120° F at 100 percent humidity were routine. The drainage tunnel was driven parallel to and two meters lower than the haulage-ventilation tunnel.

Automatic control and other modern devices installed in the newly completed concentrator of The Anaconda Company at Butte, Mont., were described by two articles.[20] A severe size limitation was imposed on instrumentation by a total central control concept. Panel grouping, slope, and color were used to present hundreds of bits of inforamtion to the operator. Basically a three-color switch lighting system, using green, amber, and red lights, was used to give five bits of information on any equipment. Graphic art work was color keyed, blue for water, brown for sand feeds, etc., to draw attention to process circuits being started. All equipment symbols were black and of approximate scale and configuration. The entire plant with few exceptions, including starting and stopping equipment, was designed to be operated from the central control room.

It was reported that special flowsheets were developed in the U.S.S.R. by which copper is recovered from ore by stage grinding, classification, and flotation.[21] Relatively coarse-ground ore is treated by flotation, and the bulk of the gangue is discarded as a final tail. Concentrate thus produced is subjected to subsequent grinding and flotation to produce concentrate of high metal content. Use was made of special reagents that were stable and capable of selective fastening of air bubbles, not only to the comparatively large free particles of metallic minerals but also to their aggregates with gangue minerals.

Results of continuing laboratory research on microbiological leaching of sufide ores were published in two reports.[22] The use of a surface active agent accelerated leaching of some chalcopyrite minerals and ores. Although bacteria were discovered in 1683, their earliest activity in copper leaching was ascribed to the recovery of copper from mine water in 1670 at the present Rio Tinto mines in southwestern Spain.[23]

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[17] Argall, George O., Jr. Bethlehem's Target: Copper Production at 15¢ Per Pound and Canadian Copper Producer Studies Moly Circuit. Metal Min. and Proc., v. 1, No. 3, March 1964, pp. 28–38.

[18] Mining Engineering. Mount Isa Pilots New Methods, Pushes Expansion; Mount Lyell Tasmania's Copper Producer; Mount Morgan-Queensland Copper Producer; and Copper Development Bolsters Rum Jungle. V. 16, No. 10, October 1964, pp. 90–94.

[19] Argall, George O., Jr. Cerro de Pasco Drives Twin Headings To Drain-Ventilate Casapalca mine. World Min., v. 17, No. 12, November 1964, pp. 22–26.

[20] Mining and Minerals Engineering (London). Automatic Control at the Butte Concentrator. V. 1, No. 2, October 1964, pp. 55–58.

Wrath, William, Jr., and T. G. Fulmor. Anaconda's Butte Concentrator. Min. Eng., v. 16, No. 5, May 1964, pp. 54–78.

[21] Metal Mining and Processing. Soviet Copper Flotation Techniques Show Ingenuity. V. 10, No. 1, October 1964, pp. 34–36.

[22] Duncan, D. W., and P. C. Trussell. Advances in the Microbiological Leaching of Sulfide Ore. Can. Met. Quart., v. 3, No. 1, January–March 1964, pp. 43–55.

Duncan, D. W., P. C. Trussell, and C. C. Walden. Leaching of Chalcopyrite With Thiobacillus Ferrooxidans: Effects of Surfacants and Shaking. Applied Microbiology, v. 12, No. 2, March 1964, pp. 122–126.

A patent was issued for a process and apparatus for the precipitation of copper.[24] The process comprises passing a dilute acid solution upward and beyond a mass of finely divided metallic iron at a velocity effective dynamically to suspend the individual particles and to bring about intimate liquid-solids contact and the replacement of iron by copper.[25] The flow velocity of the solution is reduced as it rises to establish a relatively quiet stratum of finer particles above the turbulent zone of liquid-solid interaction. The process also utilizes hydrogen gas involved to control mechanisms that shut off incoming copper solution, dump the copper slurry, and add another charge of iron.

Output from the Hayden, Ariz., smelter of the American Smelting & Refining Company was increased by a modernization program consisting of new facilities for transporting, handling, and storing concentrate. Major changes also were made to increase the capacity of the reverberatory furnace.[26] Railroad cars were designed especially to transport concentrate from custom shippers as well as that produced at Asarco's mines. New sampling techniques were instituted and new facilities for bedding concentrate were constructed. An electronic computer controlled the operations of the copper converters at the smelter of Kennecott Copper Corp. at McGill, Nev.[27] Preliminary results indicated a reduction in operating costs because of more efficient utilization of materials and manpower, increased production by more output per unit cost, improved quality control, and greater safety by warning of dangers. Data punched on cards included readings from instruments in the smelter stack, a pyrometer that reads temperatures in the smelter bath, a thermocouple that records temperatures of the waste gases, results of sampling gases, weights of furnace charges, and assays of mattes and slags.

A combination rotary drill and mud gun was developed for tapping and plugging reverberatory furnaces at the smelter of Kennecott Copper Corp. at Hayden, Ariz.[28] Use of the machine permitted placing and removing longer plugs placed in tap holes in the furnace walls, resulting in the inner end of the plug being above the chilling temperature of matte. Prodding with oxygen lances was almost entirely eliminated.

A daily metallurgical balance was achieved from data obtained from an elaborate system of sampling and weighing at Nchanga.[29] The data were processed by a computer, and the program was refined to produce rapidly an accurate monthly balance for mine planning and cost accounting. Ore was produced from three deposits that varied in grade and sulfide-to-oxide ratio. Ore was processed in two separate grinding circuits that fed to three separate flotation circuits. A fourth flotation circuit treated leach plant residue for additional recovery of sulfides. Each of the four flotation circuits produced sulfide concentrate and three of the four produced oxide concentrates. One of the benefits derived from rapid determination of results of sampling was control of the flow of ore from mines and stockpiles to insure a throughput consistent in tonnage and content of both total and acid soluble copper.

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[23] Trussell, P. C., D. W. Duncan, and C. C. Walden. Biological Mining. Can. Min. Jr., v. 85, No. 3, March 1964, pp. 46–49.

[24] Back, Alexander E., K. E. Fisher, and J. Kocherhans (assigned to Kennecott Copper Corp., New York). Process and Apparatus for the Precipitation of Copper From Dilute Acid Solutions. U.S. Pat. 3,154,411, Oct. 27, 1964.

[25] Chemical & Engineering News. Kennecott System Improves Copper Recovery. V. 42, No. 44, Nov. 2, 1964, pp. 46–47.

[26] Bogert, John R. Asarco's Modernization Program Brings New Life to a 52-year-old Smelter. Metal Min. and Proc., v. 1, No. 3, March 1964, pp. 23–25.

[27] Mining and Metal Processing. Computer Controls Copper Converters at Nevada Mills. V. 1, No. 3, March 1964, p. 19.

[28] Bogert, John R. More Muscle Developed for Matte Tapping. Metal Min. and Proc., v. 1, No. 4, April 1964.

[29] Oxford, Desmond de V., and Peter H. Williams. Computerized System of Metallurgical Accounting and Control at Nchanga. Min. Eng., v. 17, No. 1, January 1965, pp. 55–59.

Kounrad, the largest open pit base metal mine in the U.S.S.R., is a true porphyry copper by international standards.[30] The mine is in the Karaguanda Region of Kazakhstan, which is considered to be one of the great copper areas of the world. Copper occurs in two ore bodies in secondary quartzite derived from granodioritic and quartz porphyries. The ore bodies are irregular in shape, are separated from each other by lean ore and barren rock, and have areas of barren quartzite within them. The oxidized zone, which now has been mined out, averaged about 150 feet in thickness. Malachite, the prevailing ore mineral, was associated with azurite, cuprite, chrysocolla, limonite, jarosite, barite, opal, and chalcedony. Chalcocite, and to a lesser degree covellite, are the principal ore minerals of the zone of enrichment that extends to a maximum depth of 650 feet. Chalcopyrite and pyrite with subordinate quantities of molybdenite, enargite, grey copper, and sphalerite, occur in the primary zone. The central part of the pit has been developed to a depth of about 550 feet. Ore is loaded with power shovels having dipper capacities of 3 and 4 cubic meters, whereas shovels with 6- to 8-cubic-meter buckets are used on the stripping benches that have banks about 60 feet high. Broken waste is loaded on trains of five dump cars of 90- to 100-ton capacity and is transported an average of 3.3 miles. Ore is loaded on trains of 5 gondolas of 100-ton capacity for transporting to flotation mills. In 30 years of mining, a total of 390 million tons of ore and waste have been removed from the mine, thus ranking it in size with the mines in Arizona of Inspiration Consolidated Copper Co. and Bagdad Copper Corp.

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[30] Voroshkevich, Sergei. Kounrad, A True Porphyry Pit, Is Russia's Largest Copper Mine. World Min., v. 18, No. 2, February 1965, pp. 20–22, 70.

Diatomite

By Benjamin Petkof[1]

◆

THE UNITED STATES maintained its position as the world's largest producer of diatomite. Both production and value of diatomite rose 5 percent over the 1963 levels.

DOMESTIC PRODUCTION

California continued to be the largest domestic diatomite producer. Nevada remained in second place, with Washington, Arizona, and Oregon supplying limited quantities. Production was reported by 13 companies operating 15 plants, unchanged from 1963.

Arizona Diatom Corp. purchased the diatomite properties of Arizona Enterprises Corp. and will bring this and other properties in the area into operation during 1965.

TABLE 1.—Diatomite sold or used by producers in the United States, 3-year totals [1]

	1945–47	1948–50	1951–53	1954–56	1957–59	1960–62
Domestic production (sales)___short tons__	640, 764	722, 670	908, 448	1, 105, 279	1, 349, 340	r1, 446, 625
Average value per ton____________________	$20. 17	$25. 55	$29. 97	$39. 21	$45. 73	$50. 08

r Revised.
[1] Annual figures are company confidential.

CONSUMPTION AND USES

Diatomite's largest single use continued to be filtration, and the quantity used for this purpose increased about 5 percent over that of 1963. However, the share of the total diatomite production for filtration remained static. Consumption of filler-grade material increased almost 9 percent over that of 1963, while the percentage of the total increased 1 percent. The quantity used for insulation decreased 2 percent, but its portion of the total production increased 1 percent. Diatomite for miscellaneous uses increased about 5 percent, but the percentage of the total quantity used remained unchanged. Miscellaneous uses included such application as abrasives, lightweight aggregates, pozzolans, absorbents, insecticides, paints, and soil conditioners.

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[1] Commodity specialist, Division of Minerals.

TABLE 2.—Domestic consumption of diatomite, by principal use, in percent of total consumption

Use	1960	1961	1962	1963	1964
Filtration	48	48	48	47	47
Fillers	25	24	23	23	23
Insulation	5	5	5	5	5
Miscellaneous	22	23	24	25	25

PRICES

Prices of diatomite showed some variation from those of the previous year, increasing slightly for material used for insulation and miscellaneous uses, decreasing for filter and filler material, and remaining unchanged for abrasives.

TABLE 3.—Average annual value per ton of diatomite, by uses

Use	1963	1964	Use	1963	1964
Filtration	$62.26	$61.92	Fillers	$50.07	$47.37
Insulation	49.91	51.66	Miscellaneous	30.20	32.39
Abrasives	137.00	137.00			
			Weighted average	50.72	50.62

FOREIGN TRADE

The year's imports were 572 short tons valued at $21,209. About 59 percent of this material came from Canada, with Mexico, the United Kingdom, and France supplying the remainder. Some diatomite was exported by domestic producers. However, the U.S. Department of Commerce maintains no records on diatomite exports. Tariff regulations in 1964 allowed duty-free imports of diatomite.

WORLD REVIEW

The United States maintained its position as the world's leading producer of diatomite in 1964. Other principal free world producers were France, West Germany, Italy, and Denmark.

Canada.—The Cariboo Diatomite Co. of Canada has requested the British Columbia Research Council to develop methods for upgrading the diatomite available in deposits near Quesnel, British Columbia.[2]

South Africa, Republic of.—Production during 1963 decreased to 220 short tons from 647 in 1962. Of this quantity 143 tons were sold locally, compared with 530 tons in 1962.[3]

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[2] Mining Journal (London). Columbian Diatomite. V. 262, No. 6698, Jan. 3, 1964, p. 11.
[3] Bureau of Mines. Mineral Trade Notes. V. 59, No. 2, August 1964, p. 19.

TABLE 4.—World production of diatomite, by countries [1] [2]

(Short tons)

Country [1]	1955-59 (average)	1960	1961	1962	1963	1964
North America:						
Canada	34	44	214	211	798	584
Costa Rica	3,226	2,425	717	827	[e] 2,000	[e] 2,000
Guatemala	14,997	---	---	---	---	---
Nicaragua	[3] 1,887	2,249	2,976	1,414	[e] 1,760	[e] 1,760
United States	417,238	[4] 482,202	[4] 482,202	[4] 482,202	[4] 482,202	[4] 482,202
South America:						
Argentina	4,624	117	1,286	180	3,797	[e] 3,800
Chile	110	---	---	---	---	---
Colombia	230	440	330	165	2,425	[e] 2,425
Peru	89	1,127	2,048	1,624	2,422	[e] 2,425
Europe:						
Austria	4,467	4,431	5,993	4,613	4,339	[e] 4,240
Denmark:						
Diatomite [e]	16,500	17,600	21,500	22,000	22,000	22,000
Moler [e] [5]	197,800	204,300	212,900	230,800	212,000	211,000
Finland	2,060	1,457	805	1,320	2,535	[e] 2,500
France [6]	90,162	140,468	118,429	140,093	[e] 140,000	[e] 140,000
Germany, West [6] (marketable)	65,215	51,138	72,200	67,800	98,530	[e] 98,500
Italy	31,384	51,888	63,050	[e] 63,000	62,379	[e] 62,400
Portugal [6]	1,866	1,172	847	1,598	2,067	[e] 2,100
Spain [6]	13,450	13,840	19,346	13,352	11,229	[e] 11,000
Sweden [7] (marketable)	1,242	472	732	252	[e] 330	[e] 330
U.S.S.R. [e]	(8)	300,000	330,000	330,000	340,000	340,000
United Kingdom	26,132	16,553	24,920	22,800	[e] 22,800	[e] 22,800
Yugoslavia	[e] 4,500	[e] 5,000	[e] 5,000	5,000	[e] 11,600	[e] 11,600
Asia: Korea, South	2,232	2,646	1,989	758	1,867	[e] 43,400
Africa:						
Algeria	29,181	24,266	35,213	30,565	19,401	[e] 19,400
Kenya	4,278	3,791	3,537	3,207	3,677	[e] 3,600
Mozambique	13	103	397	385	---	---
South Africa, Republic of	570	346	137	647	220	[e] 550
Southern Rhodesia [6]	148	164	409	423	301	347
United Arab Republic (Egypt)	417	805	332	55	[e] 55	[e] 55
Oceania:						
Australia	5,909	5,218	6,067	8,189	6,533	[e] 3,500
New Zealand	3,760	6,992	3,961	2,099	1,796	[e] 1,800
World total [e] [1] [2]	1,310,000	1,550,000	1,645,000	1,660,000	1,690,000	1,720,000

[e] Estimate.

[1] Diatomaceous earth is produced in Brazil, Bulgaria, and Japan, but data on output are not available; estimates are included in total. Hungary and Rumania may produce diatomaceous earth, but data are not available, and no estimates are included in total.

[2] This table incorporates some revisions. Data do not add exactly to totals shown because of rounding where estimates are included in the detail.

[3] 1 year only, 1959 was 1st year of commercial production.

[4] Average annual production, 1960–62.

[5] Data represent estimates of moler earth used as a raw material in making refractory bricks plus moler earth exported in bulk form.

[6] Includes Tripoli.

[7] Includes calcined.

[8] Data not available; estimate included in total.

TECHNOLOGY

The operation of rapid sand, pressure diatomite, and vacuum diatomite filters was compared, using coagulated water. All three filter systems were used successfully. Sand filters provided larger quantities of water per filter cycle and required less power for operation than either diatomite type. The diatomite filters were more expensive than comparable sand filters but saved space and eliminated some piping and valves.[4]

An optical method to distinguish uncalcined diatomite from calcined material required the use of a modified Christiansen filter made from a paste of the diatomite in a liquid with a refractive index of 1.485 placed between two miscroscope slides. Calcined material is colored when observed at a window. Uncalcined material shows no color dispersion. The method has value with a pure sample, but results were confusing when used with mixtures.[5]

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[4] Schmitt, Richard P. Evaluation of Diatomite Filters for Water Plants. J. Am. Water Works Assoc., v. 56, No. 8, August 1964, pp. 1047–1054.

Laundry waste was treated with active carbon and filtered through diatomite to remove sodium alklbenzene sulfonate.[6]

An experimental pyrotechnic delay mixture using diatomite was reported.[7]

Diatomite from the Carpathian Mountains was analyzed, data were reported, and possible utilization was discussed.[8]

The streaming potentials for various grades of prepared diatomite were measured in a suitable laboratory cell, and the zeta (ion gradient) potentials were calculated from the streaming potential data. The zeta potential varied with resistivity of the water used in the streaming potential measurements, variety of diatomite, and solution used. The zeta potential of the diatomite was reversible from negative to positive by application of polyvalent cations before or during filtration.[9]

Data were obtained relating to the hydraulic and particle size characteristics of commercial filter-grade diatomites. Methods used to determine soil particle size were applied to diatomite, and their reproducibility was compared. The permeability was investigated by observing the impermeability constant K_3. The methods used to determine particle size and permeability would be adequate to evaluate the specification of commercially supplied diatomites.[10]

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[5] Grossman, Germain C. (Bausch and Lomb, Inc., Rochester, N.Y.) New Developments in Phase and Dispersion Staining Microscopy for the Examination of Dust Samples. Am. Ind. Hyg. Assoc. J., v. 25, No. 1, 1964, pp. 25–27; Chem. Abs., v. 60, No. 12, June 8, 1964, col. 15045d.

[6] Flynn, John M. Launderette Waste Treatment System. Water Sewerage Works, v. 110, No. 2, 1963, pp. 83–84; Chem. Abs., v. 60, No. 12, June 8, 1964, col. 14246d.

[7] McIntyre, R. E. Component and Process Variation for Tungsten Delay Variations. National Aeronautics and Space Administration Doc. N63–21655, 1963, 10 pp.; Chem. Abs., v. 60, No. 7, Mar. 30, 1964, col. 7860f.

[8] Kryzanowsky, M. The Diatomites From Leszawka (the Carpathians). (Prezeds. Geol. Krakow, Poland) Przeglad Geologiczny (Geological Review) (Warsaw, Poland), 10, 3, 1962; Chem. Abs., v. 61, No. 6, Sept. 14, 1964, col. 6797f.

[9] Oulman, Charles S., and E. Robert Baumann. Streaming Potentials in Diatomite Filtration of Water. J. Am. Water Works Assoc., v. 56, No. 7, July 1964, pp. 915–930.

[10] Dillingham, James H., and E. Robert Baumann. Hydraulic and Particle Size Characteristics of Some Diatomite Filter Aids. J. Am. Water Works Assoc., v. 56, No. 6, June 1964, pp. 793–808.

Feldspar, Nepheline Syenite, and Aplite

By J. Robert Wells[1]

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FELDSPAR

DOMESTIC FELDSPAR PRODUCTION sustained by continued high demand from the manufacturers of glass and ceramics, rose to a record level, more than 12 percent higher than that of the previous record in 1956. Output of plate and rolled glass in the United States advanced about 5 percent beyond that in 1963, largely as a consequence of increased building construction and expanding automobile manufacture. The container glass industry, although faced with severe competition from plastics, metals, and other container materials, also contributed to the greater feldspar requirement with a similar advance.

TABLE 1.—Salient feldspar statistics

	1955-59 (average)	1960	1961	1962	1963	1964
United States:						
Crude:						
Sold or used by producers[1] long tons	525,424	502,380	496,808	492,476	548,954	629,894
Value thousands	$4,988	$4,779	$5,120	$5,076	$5,524	$6,132
Average value per long ton	$9.49	$9.51	$10.31	$10.31	$10.06	$9.74
Imports for consumption long tons	111	44	24	33	68	10
Value thousands	$7	$5	$2	$1	$2	$1
Average value per long ton	$62.10	$106.95	$84.38	$39.55	$23.29	$84.00
Consumption, apparent[2] long tons	525,535	502,424	496,832	492,509	549,022	629,904
Ground:						
Sold by merchant mills[3] short tons	547,539	528,348	541,626	527,347	598,706	704,595
Value thousands	$7,760	$7,079	$6,694	$6,703	$7,353	$8,128
Average value per short ton	$14.17	$13.40	$12.36	$12.71	$12.28	$11.54
Imports for consumption long tons	3,668	6,980	2,529	3,297	3,006	3,170
Value thousands	$63	$110	$63	$87	$81	$85
Average value per long ton	$17.14	$15.69	$24.86	$26.45	$26.88	$26.95
World: Production long tons	1,300,000	1,550,000	1,590,000	1,590,000	1,690,000	1,770,000

[1] See table 2 for distribution of feldspar by derivation.
[2] Measured by quantity sold or used by producers plus imports.
[3] See table 4 for distribution of feldspar by derivation.

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[1] Commodity specialist, Division of Minerals.

DOMESTIC PRODUCTION

Crude Feldspar.—North Carolina, maintaining its long-established position as the foremost crude feldspar producing State, furnished over 51 percent of the reported domestic supply in 1964. California and Connecticut were also unchanged in rank, being second and third, respectively. Over 92 percent of North Carolina's total production of crude feldspar was made up of flotation concentrate, almost the same proportion as in the previous year. The feldspar processing plant of the Northwest Beryllium Corp. at Keystone, S. Dak., destroyed by fire early in 1964, was rebuilt and resumed operation before the end of the year.

Hand-cobbed feldspar, flotation concentrate, and the feldspar content of feldspar-silica mixtures are all included in the crude feldspar data.

Ground Feldspar.—Ground feldspar was produced by 20 mills in 11 States. One mill in Colorado and one in Tennessee, both operating in 1963, were inactive in 1964. Sales by merchant mills increased 18 percent in volume and 11 percent in value in 1964. States leading in the production of ground feldspar were North Carolina, California, Connecticut, Georgia, and South Carolina, in descending order. The combined output of these five States amounted to almost 90 percent of the total domestic production in 1964.

TABLE 2.—Crude feldspar sold or used by producers in the United States

Year	Derivation of feldspar [1]							
	Hand-cobbed		Flotation concentrate		Feldspar-silica mixtures [2]		Total	
	Long tons	Value (thousands)	Long tons	Value (thousands)	Long tons	Value (thousands)	Long tons	Value (thousands)
1955–59 (average)	215,484	$1,675	237,907	$2,684	72.033	$629	525,424	$4,988
1960	147,912	1,123	278,503	2,881	75,965	775	502,380	4,779
1961	116,503	788	307,468	3,580	72,837	752	496,808	5,120
1962	113,168	783	324,462	3,806	54,846	487	492,476	5,076
1963	93,488	643	364,676	3,885	90,790	996	548,954	5,524
1964	88,046	804	423,487	4,110	118,361	1,218	629,894	6,132

[1] Partly estimated.
[2] Feldspar content.

TABLE 3.—Ground feldspar sold by merchant mills [1] in the United States

Year	Mills	Domestic feldspar	
		Short tons	Value (thousands)
1955–59 (average)	24	[2] 547,539	[2] $7,760
1960	24	[3] 528,348	[3] 7,079
1961	21	541,626	6,694
1962	21	527,347	6,703
1963	22	598,706	7,353
1964	20	704,595	8,128

[1] Excludes potters and others who grind for consumption in their own plants.
[2] Includes Canadian feldspar, 1958–59.
[3] Includes Canadian feldspar.

TABLE 4.—Ground feldspar sold by merchant mills in the United States, by derivation[1] and uses

(Short tons)

Year	Hand-cobbed					Flotation concentrate				
	Glass	Pottery	Enamel	Other	Total	Glass	Pottery	Enamel	Other	Total
1955–59 (average)	53,987	115,010	27,073	20,602	216,672	176,709	64,697	---------	15,135	256,541
1960	31,171	59,546	21,418	32,267	144,402	206,784	87,133	1,315	12,870	308,102
1961	23,248	56,875	17,160	26,083	123,366	232,365	88,170	4,012	12,135	336,682
1962	26,323	45,612	(2)	45,650	117,585	215,941	96,828	(2)	35,605	348,374
1963	6,863	58,497	(2)	39,128	104,488	240,783	(2)	(2)	151,777	392,560
1964	(2)	51,703	(2)	45,952	97,655	255,907	(2)	(2)	221,169	477,076

Year	Feldspar-silica mixtures[3]					Grand total				
	Glass	Pottery	Enamel	Other	Total	Glass	Pottery	Enamel	Other[4]	Total
1955–59 (average)	65,387	2,219	---------	6,720	74,326	296,083	181,926	27,073	42,457	547,539
1960	56,727	5,872	2,416	10,829	75,844	294,682	152,551	25,149	55,966	528,348
1961	65,950	6,983	---------	8,645	81,578	321,563	152,028	21,172	46,863	541,626
1962	50,993	4,726	---------	5,669	61,388	293,257	147,166	27,391	59,533	527,347
1963	65,541	(2)	---------	36,117	101,658	313,187	195,510	24,068	65,941	598,706
1964	(2)	(2)	---------	129,864	129,864	349,715	247,474	21,925	85,481	704,595

[1] Partly estimated.
[2] Included with "Other" to avoid disclosing individual company confidential data.
[3] Feldspar content.
[4] Includes soaps, abrasives, and other ceramic and miscellaneous uses.

CONSUMPTION AND USES

Crude Feldspar.—In 1964 as usual there was practically no end use of feldspar in the unprocessed condition. The majority of users filled their feldspar requirements by purchase of material already ground either by the primary producers or by merchant grinders. A relatively small amount of crude feldspar was sold, however, to some pottery, soap, and enamel manufacturers to be ground to their preferred specifications in their own mills.

Ground Feldspar.—In 1964 the glass, pottery, and enamel industries consumed 88 percent of the ground feldspar produced in the United States. The quantity used in glass making increased by 37,000 tons, amounting to 50 percent of the total ground feldspar sold, compared with 52 percent the year before. Pottery manufacture consumed 52,000 tons of ground feldspar more than in the previous year, accounting for 35 percent of the total amount sold, compared with 33 percent in 1963. The enamel industry purchased about 2,000 tons less in 1964 than in 1963, consuming about 3 percent of the total 1964 sales, compared with 4 percent in 1963.

California was first in feldspar consumption in 1964, regaining the lead from Ohio, which returned to second place. Next in order of consumption were Illinois, New Jersey, and Pennsylvania. Together these five States used 53 percent of the ground feldspar sold in the United States, compared with 59 percent in 1963. Consumption decreased in three of these States and increased in two, with the decline in Ohio nearly balanced by a marked advance in California.

TABLE 5.—Ground feldspar shipped from merchant mills in the United States

(Short tons)

Destination	1960	1961	1962	1963	1964
California	91,452	99,149	79,075	78,164	120,804
Illinois	54,089	55,815	46,283	49,822	73,967
Indiana	28,426	39,700	19,139	20,688	20,998
Maryland	16,017	14,092	11,748	11,636	(1)
Massachusetts	5,101	6,235	4,603	4,231	4,407
New Jersey	25,989	38,245	53,640	62,336	58,089
New York	19,701	16,850	21,696	23,631	22,117
Ohio	67,324	67,304	76,287	122,242	80,119
Pennsylvania	60,907	55,947	34,843	40,567	37,805
Texas	21,440	22,994	22,502	(1)	(1)
West Virginia	36,216	27,384	(1)	18,714	26,638
Wisconsin	9,677	8,727	(1)	(1)	(1)
Other destinations [2]	92,009	89,184	157,531	166,675	259,651
Total	528,348	541,626	527,347	598,706	704,595

[1] Included with "Other destinations."

[2] Includes Alabama (1960–62); Arkansas; Colorado; Connecticut; Florida (1960–61); Georgia (1960 and 1963–64); Hawaii (1961); Kentucky; Louisiana; Maine (1960); Michigan; Minnesota; Mississippi; Missouri; Oklahoma; Rhode Island; South Carolina (1962–64); Tennessee (1960 and 1964); Utah (1960); Vermont (1960 and 1962–64); Virginia (1963–64); Washington (1960–62 and 1964); shipments that cannot be separated by States; and shipments indicated by footnote 1. Also includes exports to Canada; Colombia (1961); Cuba (1960); England (1962); Mexico; Panama; Philippines (1963–64); Venezuela (1960–63); and small quantities to other countries.

PRICES

Average values of crude and ground feldspar reported to the Bureau of Mines are shown in table 1.

The value per ton of both flotation concentrate and feldspar-silica mixtures decreased significantly in 1964, while there was a sharp rise in the value per ton of hand-cobbed feldspar over that reported in 1963.

Illinois had the highest average price of $26.59 per short ton for ground feldspar, followed by New Hampshire with $21.35, and Virginia with $20.32. Feldspar for use in soaps and abrasives sold for the highest average price, $19.46 per long ton.

Prices quoted for ground feldspar in E&MJ Metal and Mineral Markets for December 28, 1964, were as follows: North Carolina, bulk, 20 mesh, semigranular, $9.00 per ton; 40 mesh, glass grade, $13.50 per ton; 200 mesh, $17 to $21 per ton; 325 mesh, $18 to $22 per ton. The only change from prices quoted at the end of the previous year was in that of the 20 mesh material, previously quoted at $7.50 per ton for several years.

FOREIGN TRADE

Ground feldspar exports were 14 percent higher than in 1963, according to reports from grinders. Canada, Mexico, and the Philippines were reported as destinations.

For the first time in more than 40 years there were no recorded imports of either crude or ground Cornwall stone from the United Kingdom.

TABLE 6.—U.S. imports for consumption of feldspar[1]

Year	Crude		Ground		Year	Crude		Ground	
	Long tons	Value	Long tons	Value		Long tons	Value	Long tons	Value
1955-59 (average)	111	$6,893	3,668	$62,857	1962	33	$1,305	3,297	$87,205
1960	44	4,706	6,980	109,547	1963	68	1,584	3,006	80,795
1961	24	2,025	2,529	62,859	1964	10	840	3,170	85,434

[1] All from Canada, except 39 long tons ($1,724) of ground feldspar from Norway in 1963 and 30 long tons ($1,255) in 1964.

Source: Bureau of the Census.

WORLD REVIEW

World production of feldspar was about 6 percent higher than in 1963. The production pattern has remained relatively stable in recent years, although the annual production of the Republic of South Africa, after a number of years of continued growth in which it had expanded four-fold since 1959, dropped more than 14 percent in 1964. The United States furnished about 36 percent of the total world output in 1964, compared with 32 percent in 1963. In Bulgaria plans were announced for the construction of facilities to mine and process ore from newly discovered pegmatite deposits to yield 20,000 tons of feldspar annually.

TECHNOLOGY

Pilot-plant testing was completed on a process for recovering beryl, feldspar, and spodumene by flotation beneficiation of tailing from the Foot Mineral Co. plant at Kings Mountain, N.C.[2]

Technologic innovations reported from the Soviet Union included the application of ultrasonic cleaning as a preliminary to flotation treatment of feldspar ores[3] and the development of a two-stage electrical process for the separation and concentration of feldspathic materials from pegmatite.[4]

A new mineral in a hot-spring deposit at Sulfur Bank, Lake County, Calif., the first ammonium aluminosilicate found in nature, was identified as the ammonium analogue of monoclinic potassium feldspar and was named buddingtonite.[5] The natural occurrence of buddingtonite and the experimental work in the synthesis of other ammonium feldspars suggested that analogous minerals may exist in the ammonium-rich environments of the major planets and of comets and should be sought in carbonaceous chondrites.[6]

Analysis by X-ray diffraction and petrographic microscopy indicated that natural or synthetic potassium feldspar is not changed

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[2] Browning, James S., Thomas L. McVay, and Paul E. Bennet. Continuous Flotation of Beryl From Spodumene Mill Tailing, Foote Mineral Company, Kings Mountain, N.C. BuMines Rept. of Inv. 6466, 1964, 24 pp.

[3] Canadian Mining Journal. V. 85, No. 12, December 1964, p. 82.

[4] Mine & Quarry Engineering (London). Electrical Separation of Russian Pegmatites. V. 30, No. 2, February 1964, pp 78–82.

[5] Erd, Richard C., Donald E. White, Joseph J. Fahey, and Donald E. Lee. Buddingtonite, an Ammonium Feldspar With Zeolitic Water. Am. Mineralogist, v. 49, Nos. 7 and 8, July–August 1964, pp. 831–850.

[6] Barker, Daniel S. Ammonium in Alkali Felspars. Am. Mineralogist, v. 49, Nos. 7 and 8, July–August 1964, pp. 851–858.

TABLE 7.—World production of feldspar by countries [1] [2]

(Long tons)

Country [1]	1955–59 (average)	1960	1961	1962	1963	1964 [p]
North America:						
Canada (shipments)	16,981	12,376	9,381	8,923	7,686	7,692
United States (sold or used)	525,424	502,380	496,808	492,476	548,954	629,894
Total	542,405	514,756	506,189	501,399	556,640	637,586
South America:						
Argentina	5,183	8,418	11,474	4,853	2,950	[3] 2,950
Brazil [e]	24,600	39,000	39,000	39,000	39,000	39,000
Chile	1,019	1,095	2,280	1,138	417	568
Colombia	6,700	14,800	14,800	15,250	12,300	11,426
Peru	----------	236	992	287	309	835
Uruguay	233	713	877	692	282	[3] 282
Total [e]	38,000	64,000	69,000	61,000	55,000	55,000
Europe:						
Austria	2,772	4,573	3,907	4,976	2,077	1,603
Finland	10,228	9,158	13,303	14,920	12,620	10,560
France	116,404	135,334	170,470	170,194	170,764	[e] 147,600
Germany, West	166,943	264,204	265,450	269,770	265,120	278,355
Italy	56,412	85,076	93,204	91,126	100,211	106,868
Norway	45,633	53,337	68,895	54,100	65,000	65,300
Poland	NA	NA	NA	NA	26,300	[3] 26,300
Portugal	809	1,699	2,892	3,674	396	[3] 396
Spain	5,792	11,924	8,194	10,700	12,477	[3] 12,477
Sweden	49,010	54,517	55,868	53,348	45,100	[3] 45,100
U.S.S.R. [e]	170,000	195,000	195,000	195,000	195,000	195,000
Yugoslavia	[4] 11,715	13,780	20,215	31,578	29,413	30,068
Total [e] [1]	640,000	835,000	905,000	905,000	930,000	925,000
Asia:						
Ceylon	----------	32	106	56	109	4
Hong Kong	941	2,511	1,206	937	1,680	1,556
India	7,036	10,395	9,706	18,918	20,602	19,781
Japan [5]	45,474	91,454	50,986	46,991	53,339	[3] 53,339
Korea, South	NA	NA	NA	4,651	11,392	[3] 11,392
Pakistan, West	NA	NA	NA	55	1,220	48
Philippines	[6] 602	3,896	14,526	15,325	6,564	7,924
Viet-Nam, South	376	----------	----------	----------	----------	----------
Total	54,429	108,288	76,530	86,933	94,906	94,044
Africa:						
Eritrea	462	984	2,953	425	[e] 490	[e] 9,800
Ethiopia	----------	----------	----------	----------	----------	
Kenya	30	----------	1	----------	----------	----------
Malagasy Republic	40	----------	13	----------	(7)	----------
Rhodesia, Southern	90	----------	----------	----------	----------	----------
South Africa, Republic of	9,137	15,600	23,290	28,209	41,372	35,525
South-West Africa	----------	----------	89	465	2,197	1,893
United Arab Republic (Egypt)	[8] 490	354	----------	----------	----------	4,653
Total	10,249	16,938	26,346	29,099	44,059	51,871
Oceania: Australia	12,410	8,414	8,209	8,513	8,842	[e] 7,300
World total (estimate) [1] [2]	1,300,000	1,550,000	1,590,000	1,590,000	1,690,000	1,770,000

[e] Estimate. [p] Preliminary. NA—Not available.

[1] Feldspar is produced in China, Czechoslovakia, and Rumania, but data are not available; no estimates included in total except for Czechoslovakia.

[2] This table incorporates some revisions. Data do not add exactly to totals shown because of rounding where estimated figures are included in the detail.

[3] 1963 data.

[4] Average annual production 1958–59.

[5] In addition, the following quantities of aplite and other feldspathic rock were produced: 1955–59 (average), 75,598 tons; 1960, 91,339 tons; 1961, 132,041 tons; 1962, 168,543 tons; 1963, 211,814, tons; 1964, 260,576 tons.

[6] Average annual production 1957–59.

[7] Less than ½ unit.

[8] One year only as 1959 was first year of commercial production.

in the dry condition by elevated temperature and pressure but that, in the presence of water, conversion to a hexagonal, hydrated form is effected.[7] Fusion with sodium pyrosulfate has been found to be a valuable recourse in mineralogical analysis of feldspar samples. This fusion decomposes the layer silicates (micas) with only slight effect upon other components so that quantitative differentiation of the mineral species present is facilitated.[8] The texts were published of 40 feldspar research papers presented at The Advanced Study Institute of Feldspar in Oslo in June 1962.[9]

NEPHELINE SYENITE

Nepheline syenite from Arkansas, the only domestic source currently exploited, is unsuitable because of its high iron content for uses other than as roofing granules and similar applications. Production data on this material are included in the Stone chapter of the Minerals Yearbook. Nepheline syenites of glass and ceramic grade, mostly purchased by glass manufacturers in the northeastern United States, was supplied by Canada. Canadian production of this mineral in 1963, the last year for which data are available, was about 255,000 short tons, valued at about $2.7 million, of which 80 percent was exported, 72 percent to the United States and 5 percent to the United Kingdom.

The quoted price of glass-grade nepheline syenite, f.o.b. plant, Ontario, was $10.00 per short ton in 1964, $1.00 per ton higher than in 1963. For the finest ground, high-quality material, bagged and in carlots, a price of $28.50 per ton was quoted in Canadian Chemical Processing for October 1963.[10]

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[7] Seki, Yotaro, and George C. Kennedy. The Breakdown of Potassium Feldspar, $KAlSi_3O_8$, at High Temperatures and High Pressures. Am. Mineralogist, v. 49, Nos. 11 and 12, November–December 1964, pp. 1688–1706.

[8] Kiely, P. V., and M. L. Jackson. Selective Dissolution of Micas From Potassium Feldspars by Sodium Pyrosulfate Fusion of Soils and Sediments. Am. Mineralogist, v. 49, Nos. 11 and 12, November–December 1964, pp. 1648–1659.

[9] Christie, O. H. J. (ed). Feldspar Volume. Norsk Geologisk Tidsskrift, v. 42, No. 2. (Norsk Geologisk Forening, Oslo, Norway), 1962, 606 pp. (reviewed in Am. Mineralogist, v. 49, Nos. 3 and 4, March–April 1964, p. 451.)

[10] Reeves, J. E. Nepheline Syenite (1963 Preliminary). Canada Dept. Mines and Tech. Surveys, Ottawa, April 1964, p. 5.

TABLE 8.—U.S. imports for consumption of nepheline syenite

Year	Crude		Ground		Year	Crude		Ground	
	Short tons	Value	Short tons	Value		Short tons	Value	Short tons	Value
1955-59 (average)	194	$4,269	153,687	$2,230,708	1962	------	--------	188,833	$2,084,766
1960	900	18,652	184,464	2,403,079	1963	272	$4,731	196,567	2,109,441
1961	1,167	20,224	186,297	2,026,239	1964	------	--------	205,695	2,320,065

Source: Bureau of the Census.

World Review.—Canada continued to be the leading producer of nepheline syenite, with production up about 15 percent from that of 1963.[11] Most of the processed material was exported to the United States. Two operators, each with a plant capacity of 600 tons per day, mined and processed nepheline syenite at Blue Mountain near Peterborough, Ontario, site of the only deposit being exploited in Canada.[12]

Mining and processing of ore from a large nepheline syenite deposit on the Norwegian island of Stjernoy yielded high-quality matrial of glass grade and of ceramic grade.[13] Norwegian production of nepheline syenite was about 25,000 short tons in 1963 and 34,000 tons in 1964.

A nepheline concentrate, acceptable as raw material for manufacturing green glass or, optionally, as a source of aluminum, was produced in the U.S.S.R. on the Kola Peninsula as a byproduct of processing aplite-nephelite rock from the Khibiny deposits.[14]

Technology.—The use of nepheline syenite as a component of a ceramic slip for spraying expanded aggregate particles that are used in the manufacture of lightweight, multicolored clay tile, clay brick, and other structural units was patented.[15]

APLITE

Sales of ground aplite in 1964, mainly to manufacturers of amber glass, were 14 percent more in quantity than in 1963, and the total value was 21 percent higher. Actual production and sales data are withheld to avoid disclosing individual company confidential information.

M & T Chemicals, Inc., treating crude ore in Hanover County, Virginia, by electrostatic concentration, and Consolidated Feldspar Department of International Minerals & Chemical Corp., using a magnetic separation method in Nelson County, Virginia, were the only domestic producers of aplite in 1964.

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[11] Canada Department of Mines and Technical Surveys. The Canadian Mineral Industry in 1964, Preliminary. Mineral Information Bulletin MR 79, February 1965, pp. 2–3.

[12] Page 1 of work cited in footnote 10.

[13] Page 3 of work cited in footnote 10.

[14] Page 3 of work cited in footnote 10.

[15] Blair, W. H. Ceramic Structural Products. U.S. Pat. 3,143,433, Aug. 4, 1964.

Ferroalloys

By Gilbert L. DeHuff[1]

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SUPPORTED by a record steel production, the ferroalloy industry saw a marked change for the better in 1964. With the improvement worldwide in scope, the pressure of imports on the U.S. producer was relieved although by no means permanently removed. Total domestic production of ferroalloys, as reported to the Bureau of Mines, increased 22 percent and shipments increased 27 percent over 1963. Value of the shipments increased 12 percent.

More detailed information concerning the more important ferroalloys covered in this chapter may be found in the particular commodity chapters concerned.

DOMESTIC PRODUCTION

In 1964, 55 ferroalloy plants in 18 States made nearly 2.5 million tons of ferroalloys; 10 of the plants were blast furnace; 41 were electric furnace and 2 of these made some ferroalloys by a thermic process as well; 3 used only a thermic process; and 1 used a patented fused-salt electrolytic process. Ohio was the principal producing State with 774,000 short tons, followed by Pennsylvania with 586,000 tons. Alabama, Florida, Idaho, Illinois, Iowa, Kentucky, Montana, New Jersey, New York, Oregon, South Carolina, Tennessee, Texas, Virginia, Washington, and West Virginia reported production, also.

At the end of the year, Interlake Iron Corp. merged with Acme Steel Co. to create a new, fully integrated, steel company under the name of Interlake Steel Corp. Prior to the merger, Interlake Iron Corp. had taken steps to improve its ability to produce ferroalloys, as reported under Technology in this chapter and in the Ferroalloys chapter of the 1963 Minerals Yearbook.

Chromium Mining and Smelting Corp., Ltd., completed a program of plant consolidation by closing its Riverdale, Ill., plant in May, and transferring its exothermic chromium alloy operations to the Woodstock (Memphis), Tenn., plant of its subsidiary, Montana Ferro-Alloys Co., Inc. Improvements made at the latter location included an automated exothermic production unit, and other changes which resulted in maintenance of the productive capacity previously provided by the two plants.

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[1] Commodity specialist, Division of Minerals.

The Niagara Falls, N.Y., ferroalloy plant of Union Carbide Corp. was transferred in the middle of the year to the corporation's Olefins Division, and much of the furnace equipment moved to other plants. Although welding flux, and possibly some special ferroalloys, may continue to be produced at Niagara Falls, calcium carbide and acetylene henceforth were to be its principal products.

The Roane electric furnace plant of Tennessee Products & Chemical Corp. at Rockwood, Tenn., was operated by that company for the first three quarters of the year, and continued to operate in the last quarter under lease to Union Carbide Corp.

TABLE 1.—Ferroalloys produced and shipped from furnaces in the United States

Alloy	1963				1964			
	Production		Shipments		Production		Shipments	
	Gross weight (short tons)	Alloy element contained (average percent)	Gross weight (short tons)	Value (thousands)	Gross weight (short tons)	Alloy element contained (average percent)	Gross weight (short tons)	Value (thousands)
Ferromanganese[1]								
Blast furnace	468,438	76.7	522,526	$77,965	617,023	77.6	601,943	$82,845
Electric furnace[2]	282,760	78.1	279,587	47,111	312,463	78.1	340,342	52,259
Total	751,198	77.2	802,113	125,076	929,486	77.8	942,285	135,104
Silicomanganese	151,590	65.8	154,836	24,910	202,857	65.9	213,566	29,970
Ferrosilicon	439,074	55.7	448,008	76,555	554,642	52.5	576,287	86,151
Silvery iron:								
Blast furnace	61,549	9.5	68,904	5,048	70,832	10.2	73,674	4,808
Electric furnace	132,628	17.3	133,172	11,005	151,749	16.0	148,880	11,946
Total	194,177	14.9	202,076	16,053	222,581	14.2	222,554	16,754
Chromium alloys:								
Ferrochromium[3]	231,741	66.1	235,374	63,962	276,404	66.9	308,421	79,217
Other chromium alloys[4]	82,469	38.9	79,352	18,260	72,694	39.6	83,819	20,094
Total	314,210	58.9	314,726	82,222	349,098	61.2	392,240	99,311
Ferrotitanium	2,889	26.3	3,058	2,536	4,231	27.2	4,157	3,480
Ferrophosphorus	102,028	23.9	77,827	2,877	115,657	23.9	211,727	5,840
Ferrocolumbium and ferrotantalum columbium	1,356	58.1	1,256	4,990	708	57.9	862	3,210
Ferronickel	21,807	49.2	22,208	53,207	23,187	48.5	23,441	56,330
Other[5]	35,055	36.1	61,970		61,579	29.2	67,038	
Grand total	2,013,384	59.0	2,088,078	388,426	2,464,026	58.9	2,654,157	436,150

[1] Includes briquets.
[2] Includes fused-salt electrolytic.
[3] Includes low- and high-carbon ferrochromium and chromium briquets.
[4] Includes ferrochrome-silicon, exothermic chromium additives, and other chromium alloys.
[5] Includes Alsifer, ferroboron, ferromolybdenum, ferrotungsten, ferrovanadium, simanal, spiegeleisen, zirconium-ferrosilicon, ferrosilicon-zirconium, and other miscellaneous ferroalloys.

At the Charleston, S.C., plant of Pittsburgh Metallurgical Co., a division of Air Reduction Co., two large electric furnaces replaced five smaller furnaces and increased the plant capacity for production of ferroalloys. Because of location of this plant on tidewater, the company has been able to export its ferrochromium and ferrosilicon products to advantage. Two submerged arc furnaces, having hearth diameters of 40 feet, were under construction at the company's Calvert

City, Ky., plant. When completed in 1965, each will be able to produce 250 tons of alloys per day.

TABLE 2.—Government inventory of ferroalloys (stockpile grade), Dec. 31, 1964

(Short tons)

Alloy	National (strategic) stockpile	CCC and supplemental stockpile	Total
Ferrochromium:			
High-carbon	126,171	262,076	388,247
Low-carbon	127,729	188,647	316,376
Ferrochromium-silicon	25,643	30,528	56,171
Ferrocolumbium (contained columbium)	224		224
Ferrotantalum columbium (contained columbium and tantalum)	70		70
Ferromanganese, high-carbon	142,739	835,916	978,655
Ferromolybdenum (contained molybdenum)	2,013		2,013
Ferrotungsten (contained tungsten)	826		826
Ferrovanadium	1,765		1,765

At Keokuk, Iowa, the Keokuk Electric-Metals Co. Division of Vanadium Corporation of America placed a large new electric furnace in operation in the first quarter, reportedly producing silvery pig iron with very satisfactory results.

Other units of the ferroalloy industry were engaged in modernizing production facilities to strengthen their position in the industry.

Manganese Alloys.—Thirteen companies produced ferro-manganese in 20 plants in 10 States. Seven of the plants were blast-furnace plants producing standard high-carbon ferromanganese., 12 were electric-furnace plants producing various grades of the alloy, and 1 employed a fused-salt electrolytic process to produce a low-carbon ferromanganese. Three blast furnace plants, previously out of production, were reactivated in 1964: E. J. Lavino & Co., Reusens (Lynchburg), Va.; Shenango, Inc. (formerly Pittsburgh Coke & Chemical Co.), Neville Island (Pittsburgh), Pa.; and United States Steel Corp., Clairton, Pa. The Anaconda Company resumed production at its electric-furnace plant at Aanconda, Mont., but Pittsburgh Metallurgical Co. did not make ferromanganese at its Niagara Falls, N.Y., plant in 1964. Production of ferromanganese increased 24 percent; shipments increased 17 percent. The average units value of the ferromanganese shipped from electric furnaces was 9.8 cents per pound of contained manganese, compared with 10.7 cents in 1963.

Silicomanganese was made in 7 States by 7 companies in 11 electric-furnace plants. Two of the 1963 producers, Vanadium Corporation of America and the Sheffield, Ala., plant of Union Carbide Corp., did not produce in 1964. Production of silicomanganese increased 34 percent and shipments increased 38 percent. The average value of shipments decreased to 10.6 cents from 12.2 cents per pound of contained manganese.

Spiegeleisen was made by The New Jersey Zinc Co., Palmerton, Pa.; Shenango, Inc., Neville Island, Pa.; and Union Carbide Corp., Marietta, Ohio. The production by Shenango, Inc., was by blast furnace; the other two companies used electric furnaces.

Ferrosilicon.—The 10 companies that produced ferrosilicon in 1963 used the same 22 electric-furnace plants for their production in 1964. Output and shipments increased 26 and 29 percent, respectively.

Silvery Iron.—The five companies that produced silvery pig iron in 1963 continued to produce in 1964, using the same four electric-furnace plants and three blast-furnace plants. Production and shipments increased 15 and 10 percent, respectively. The unit value of the blast-furnace product decreased to 32 cents from 37 cents per pound of contained silicon; that for the electric-furnace product increased to 25 cents from 24 cents.

Chromium Alloys.—Seven companies produced ferrochromium and other chromium ferroalloys, using electric furnaces in seven States. Production increased 11 percent; shipments increased 25 percent. The average unit value of the contained chromium was 20.8 cents per pound, compared with 22.1 cents in 1963.

Molybdenum Alloys.—Molybdenum Corporation of America, Washington Pa., used both electric furnaces and a thermic process to produce ferromolybdenum; Climax Molybdenum Co., Langeloth, Pa., and Reading Alloys Co., Inc., Robesonia, Pa., used a thermic process.

Titanium Alloys.—Four companies continued to produce ferrotitanium utilizing three electric-furnace plants and one thermic facility.

Ferrophosphorus.—Seven companies made ferrophosphorus as a byproduct of the electric-furnace process for obtaining elemental phosphorus from phosphate rock. Central Farmers Fertilizer Co., Georgetown, Idaho, was no longer a producer, having closed its plant late in 1963. The facility was purchased in 1964 by El Paso Natural Gas Co., but ferrophosphorus production was not resumed. Monsanto Co. increased its ferrophosphorus productive capacity at Soda Springs, Idaho. The new plant of V-C Chemical Co. at Mount Pleasant, Tenn., produced in 1964. Total production of ferrophosphorus increased 13 percent, while shipments almost tripled to 212,000 tons.

Ferrocolumbium and Ferrotantalum-Columbium.—Five companies continued to produce ferrocolumbium, using the same three electric-furnace and two thermic facilities Average unit value on a content basis was $3.19 per pound, compared with $3.43 in 1963. Production of ferrotantalum-columbium was reported only by Shieldalloy Corp., Newfield, N.J. Both production and shipments of the two alloys combined were less than the figures reported for 1963.

Ferronickel.—Hanna Nickel Smelting Co., Riddle, Oreg., continued to be the only ferronickel producer.

Vanadium Alloys.—Four companies continued to make ferrovanadium in the same plants used in 1963. Three plants used electric furnaces and three plants used a thermic process. A new vanadium-carbon-iron alloy, competitive with ferrovanadium, was produced by Union Carbide Corp. under the trade name of Carvan.

Zirconium Alloys.—Two companies reported production of zirconium ferroalloys.

Ferroboron.—The same three plants continued to produce ferroboron. Production was reported, also, by the Cambridge, Ohio, electric-furnace plant of Vanadium Corporation of America.

Tungsten Alloys.—The two electric-furnace plants and the thermic facility that produced in 1963 continued to be the only producers of tungsten alloys in 1964.

CONSUMPTION AND USES

As reported to the Bureau of Mines, and shown in tables 4 and 5, a total of 2,255,000 tons of ferroalloys was consumed in the United States as ferroalloys and contained alloying elements, a quantity 15 percent in excess over that used in 1963. This compares with an increase in steel production of 16 percent. Approximately 77 percent of the total was consumed by the steel industry, and an additional 17 percent was used by the producers of gray and malleable iron castings. A wide variety of uses accounted for the remainder.

More detailed end-use consumption data for certain of the more important ferroalloys will be found in the particular commodity chapters concerned. However, respondents may not be in agreement in certain instances as to end-use nomenclature. For example, the distinction between carbon steels and other alloy steels is not always clear. As a consequence, some reservation is required in interpreting end-use data. In general, the need for this increases as the detail increases.

Manganese.—Consumption of manganese alloys (including both silicomanganese and manganese metal) increased 156,000 tons, or 14 percent. Consumption of silicomanganese relative to ferromanganese continued to grow at a slowly increasing rate.

Silicon.—Consumption of silicon alloys (including both silvery pig iron and silicon metal) increased 82,000 tons, or 13 percent.

Chromium.—Consumption of chromium contained in alloys and metal increased 23 percent, with a 27 percent increase in the quantity reported used for stainless steels.

Molybdenum.—Consumption of molybdenum contained in ferromolybdenum (including calcium molybdate and molybdenum silicide) increased 15 percent.

Titanium.—Ferrotitanium consumption was slightly less than that reported for 1963.

TABLE 3.—Consumption by major end uses and stocks, of silicon alloys in the United States in 1964

(Short tons)

Alloy: Type	Alloy: Silicon content (percent)	Stainless steels	Other alloy steels [1]	Carbon steels	Tool steels	Steel mill rolls	Gray and malleable castings	Aluminum base alloys	High-temperature alloys	Other nonferrous alloys	Miscellaneous uses	Total consumption	Stocks Dec. 31, 1964
Silvery pig iron	5–13	----------	511	813	----------	1,046	95,333	----------	----------	----------	1,881	99,584	8,722
Do	14–20	----------	6,658	22,622	----------	121	83,660	----------	----------	52	[2] 3,694	116,807	16,812
Ferrosilicon	[3] 21–55	7,930	69,223	93,008	988	1,225	91,223	77	243	2,838	[4] 19,512	286,267	27,196
Do	56–70	70	6,936	17,836	----------	----------	970	----------	----------	----------	[4] 3,117	28,929	2,235
Do	71–80	9,998	15,055	6,915	317	239	11,045	----------	17	29	13,523	57,138	6,731
Do	81–89	116	456	2,154	----------	168	5,603	----------	----------	22	10	8,529	1,222
Do	90–95	17	1,310	159	----------	57	323	3,030	----------	58	14	4,968	730
Silicon metal	96–99	44	738	42	4	----------	193	46,392	829	703	[5] 9,285	58,230	3,519
Ferrosilicon briquets	40–50	----------	118	281	----------	4	37,988	----------	----------	----------	----------	38,391	4,561
Miscellaneous silicon alloys [6]	----------	310	6,226	5,127	59	136	18,631	129	65	53	4,127	34,863	4,507
Total	----------	18,485	107,231	148,957	1,368	2,996	344,969	49,628	1,154	3,755	55,163	733,706	76,235

[1] Includes quantities of carbon steels because some firms failed to specify individual uses.

[2] Used mainly in high-silicon iron, and to beneficate ores.

[3] Mainly from 40 to 55 percent silicon.

[4] Used mainly in producing ferronickel.

[5] Used mainly in producing silicones and other chemical compounds.

[6] Includes calcium-silicon, calcium-manganese-silicon, silicon-manganese-zirconium, Ferrocarbo (including briquets), Alsifer, and other miscellaneous silicon alloys.

TABLE 4.—Consumption by end uses of ferroalloys as additives in the United States in 1964

(Short tons)

Alloy	Stainless steels	Other alloy steels [1]	Carbon steels	Tool steels	Gray and malleable iron castings	Other uses	Total
Ferromanganese [2]	14,424	217,584	804,714	3,834	28,180	13,933	1,082,669
Silicomanganese	8,346	49,970	111,103	863	3,865	1,077	175,224
Silicon alloys [3]	18,485	110,227	148,957	1,368	344,969	109,700	733,706
Ferrotitanium	480	871	651	23	1	187	2,213
Ferrophosphorus	15	4,268	8,467	--------	999	7,774	21,523
Ferroboron	18	64	193	1	18	8	302
Total	41,768	382,984	1,074,085	6,089	378,032	132,679	2,015,637

[1] Includes steel mill rolls.
[2] Includes spiegeleisen, manganese metal, and briquets.
[3] Includes silicon metal and silvery iron. See table 2 for more detail.

TABLE 5.—Consumption by end uses of ferroalloys as alloying elements in the United States in 1964

(Short tons of contained element)

Alloy	Stainless steels	Other alloy steels	Carbon steels	High-speed steels	Other tool steels [1]	Gray and malleable iron castings	High temperature alloys	Other uses	Total
Ferrochromium [2]	162,256	[3] 52,386	--------	996	1,805	3,756	5,552	2,393	229,144
Ferromolybdenum [4]	1,267	[3] 1,282	--------	308	223	1,534	147	496	5,257
Ferrotungsten	(5)	[6] 393	--------	429	118	--------	60	23	1,023
Ferrovanadium [7]	33	[8] 1,975	351	262	176	26	13	27	2,863
Ferrocolumbium [9]	258	282	89	1	--------	--------	89	10	729
Ferrotantalum-columbium [9]	5	--------	--------	--------	--------	--------	2	4	11
Total	163,819	56,318	440	1,996	2,322	5,316	5,863	2,953	239,027

[1] Includes hot-work and die steels.
[2] Includes other chromium ferroalloys and chromium metal.
[3] Includes quantities believed used in producing high-speed and other tool steels and stainless steels, because some firms failed to specify individual uses.
[4] Includes calcium molybdate and molybdenum silicide.
[5] Included with "Other alloy steels."
[6] Includes stainless steels, steel mill rolls, and other alloy steels.
[7] Includes other vanadium-carbon-iron ferroalloys.
[8] Includes steel mill rolls.
[9] See columbium and tantalum chapter for more detail on end uses.

Phosphorus.—Steel-industry consumption of ferrophosphorus increased 11 percent.

Columbium and Tantalum.—Combined consumption of ferrocolumbium and ferrotantalum-columbium, both on a columbium plus tantalum content basis, was up 10 percent over that reported for 1963, but the ferrotantalum-columbium portion continued to drop. There was only a 7 percent increase in the use of ferrocolumbium in the production of carbon steels, but taking carbon steels and other alloy steels together an increase of 34 percent was recorded. The use for high-temperature alloys decreased 40 percent.

Vanadium.—Consumption of vanadium as ferrovanadium (including other vanadium-carbon-iron ferroalloys) increased 24 percent. The combined use for carbon and other alloy steels increased 33 percent; carbon steels alone, as reported, increased 43 percent. Consumption for tool steels and high-temperature alloys were both down somewhat.

Boron.—Ferroboron consumption increased 31 percent to 302 tons, a large quantity for this item.

Tungsten.—A large increase of 69 percent was recorded for consumption of tungsten contained in ferrotungsten (and minor tungsten alloys).

TABLE 6.—Stocks of ferroalloys held by producers and consumers in the United States, December 31

(Short tons)

Alloy	Producer		Consumer	
	1963, gross weight	1964, gross weight	1963, gross weight	1964, gross weight
Manganese ferroalloys [1]	[r] 169,091	137,123	154,311	133,069
Silicon alloys [2]	[r] 116,524	94,095	[3] 53,229	[3] 76,235
Ferrochromium [4]	[r] 69,743	27,357	18,263	35,314
Ferrotitanium	[r] 822	896	449	666
Ferrophosphorus	[r] 156,577	60,507	[r] 26,000	28,916
Ferroboron	109	174	38	69
Total	[r] 512,866	320,152	[r] 252,290	274,269
	1963, contained element	1964, contained element	1963, contained element	1964, contained element
Ferromolybdenum [5]	W	W	875	537
Ferrotungsten	W	W	150	409
Ferrovanadium	W	W	313	603
Ferrocolumbium	232	141	137	193
Ferrotantalum-columbium	W	W	7	7
Total	[r] 1,093	670	1,482	1,749

[r] Revised. W—Withheld to avoid disclosing individual company confidential data.

[1] Includes ferromanganese, silicomanganese, spiegeleisen, manganese metal, and briquets.

[2] Includes ferrosilicon, silvery iron, and miscellaneous silicon alloys. Consumers stocks also include silicon metal.

[3] For more detail see table 2.

[4] Includes other chromium ferroalloys and chromium metal.

[5] Includes calcium molybdate and molybdenum silicide.

PRICES

Some prices dropped early in the year, but a general firming of ferroalloy prices was evident by midsummer. This was followed by a distinct upward trend in the latter half for selected items. In some instances, this was indirectly applied, wholly or in part, by transfer of freight, packaging, or warehousing costs to the buyer. Vanadium items did not follow the upward trend. For some of those alloys competing with imports, standard ferromanganese for one, the price situation was not clear.

The price of domestically produced standard high-carbon ferromanganese was weak and confused most of the year. One producer's listing had it unchanged for the year at $167.50 per long ton, f.o.b. furnaces, for lump bulk material in carload lots. One, selling without published lists, increased its price $10 per ton in December, and others announced increases effective for January 1965. In the first part of the year, imported alloy was priced significantly lower than the same grade of domestic material, but increases for imports after midyear brought the two prices closer together. August 5, the price for spiegeleisen containing 19 to 21 percent manganese increased from $84 to $87 per long ton, f.o.b. Palmerton, Pa. The price held to yearend.

October 1964, the quotations for high-carbon ferrochromium were changed from a delivered to an f.o.b. producing plant basis. Otherwise, the price remained at 19 cents per pound of contained chromium, carloads, bulk lump. The price of standard low-carbon ferrochromium, 67 to 73 percent chromium, maximum 0.025 percent carbon, increased 2 cents in July to 24.5 cents per pound of contained chromium, delivered carloads, bulk lump. In October this was changed to an f.o.b. producing plant basis.

The 50-percent silicon grade of ferrosilicon was priced until July at 12.1 cents per pound of contained silicon, delivered carloads, bulk lump. It then increased in two stages to 13.6 cents, which price prevailed through the last quarter.

Quotations for all three grades of ferrovanadium containing 50 to 55 percent vanadium were down to $2.50 per pound of contained vanadium by the end of March, after having been quoted at $2.60 for a short time. Carvan, a competitive new vanadium-carbon-iron alloy, was priced at $2.17 per pound of contained vanadium. Ferrocolumbium containing 50 to 60 percent columbium, maximum 0.40 percent carbon, and maximum 8 percent silicon, continued to be quoted at $3.00 per pound of contained columbium, ton lots, 2-inch lump, packed and delivered.

FOREIGN TRADE

The year under review was the first complete year for which the Bureau of the Census' new statistical classification of imports was in effect. Under the new classification, calcium silicide, ferroboron, and zirconium silicon no longer are classified separately; silicomanganese data (manganese silicon including silicon manganese in the old classification, ferrosilicon manganese in the new classification) are reported in both gross weight and manganese content; and the gross weight of manganese metal is reported instead of the manganese content as formerly, a change of little practical importance.

Imports for consumption of both total ferromanganese and high-carbon ferromanganese increased 43 percent on a gross weight basis because of imports for the Government from India and Chile under barter agreements. Commercial imports were at approximately the same levels as those for 1963. Silicomanganese imports for consumption, all for commercial account, were less than half those of 1963 on a manganese-content basis. Ferrosilicon imports were not large, but were somewhat higher on a silicon-content basis than were those of any of the previous 3 years. Neither ferrochromium nor ferrovanadium imports showed noteworthy changes from the totals reported for 1963.

Total exports of ferroalloys was more than three times that of 1963; ferrochromium, ferromanganese, ferromolybdenum, and ferrophosphorus, all showed large increases.

TABLE 7.—U.S. imports for consumption of ferroalloys and ferroalloy metals

Alloy	1963			1964		
	Gross weight (short tons)	Content (short tons)	Value	Gross weight (short tons)	Content (short tons)	Value
Calcium silicide	560	(1)	$159,575	(2)	(2)	(2)
Chromium metal	861	(1)	1,308,120	733	(1)	$1,108,941
Ferroboron	11	(1)	17,194	(2)	(2)	(2)
Ferrocerium and other cerium alloys	8	(1)	48,797	5	(1)	47,895
Ferrochrome and ferrochromium—						
Containing 3 percent or more carbon	6,532	3,961	1,043,275	7,470	4,555	1,257,100
Containing less than 3 percent carbon	22,511	15,984	5,763,649	18,652	13,141	4,525,997
Ferromanganese—						
Containing not over 1 percent carbon	628	560	252,070	593	534	217,873
Containing over 1 and less than 4 percent carbon	15,666	12,581	2,867,241	22,892	17,832	3,905,799
Containing not less than 4 percent carbon	132,336	102,236	13,854,429	189,141	143,708	21,687,448
Ferromolybdenum, molybdenum metal, compounds, alloys and scrap (molybdenum content)	(1)	37	174,267	(1)	8	48,422
Ferronickel	----------	----------	----------	(3)	(1)	964
Ferrophosphorus	3	(1)	209	80	(1)	6,990
Ferrosilicon	13,357	2,376	743,765	13,161	3,044	908,387
Ferrotitanium	41	(1)	35,145	28	(1)	19,481
Ferrotungsten	546	441	608,589	121	98	136,006
Ferrovanadium	443	(1)	1,186,697	395	(1)	840,651
Ferrozirconium	----------	----------	----------	28	(1)	10,713
Ferroalloys, n.e.s	52	(1)	130,277	115	(1)	290,328
Manganese metal	[4] 2,631	(4)	943,902	878	(1)	328,424
Silicomanganese (manganese content)	(1)	[r] 14,252	2,318,003	10,841	6,869	1,126,763
Tungsten alloys (unwrought) and scrap (tungsten content)	(1)	21	40,290	(1)	17	25,948
Tungsten metal (lump, grains, or powder) and tungsten carbide (tungsten content)	(1)	[r] 74	[r] 273,781	(1)	30	126,075
Zirconium silicon	30	(1)	5,582	(2)	(2)	(2)

[r] Revised.
[1] Not recorded.
[2] No longer separately classified.
[3] Less than ½ unit.
[4] Effective Sept. 1, 1963, reported in gross weight. However because gross weight and manganese content are almost the same, the total is tabulated here under gross weight.

Source: Bureau of the Census.

WORLD REVIEW

European Economic Community (EEC).—Effective October 13 until the end of 1964, the import duty on ferrophosphorus containing 15 percent phosphorus was suspended because of a supply shortage.

France.—Rationalization of the ferroalloy interests of Soc. d'Electro-Chimie, d'Electro-Metallurgie et des Acieries Electriques d'Ugine, and Pechiney Compagnie de Produits Chimiques et Electrometallurgiques, resulted in ferrochromium sold by the two companies being produced by the former, while the latter produced the ferrotitanium and other alloys common to both.[2]

Italy.—The ferroalloy industry was reported adversely affected by imports from both within and without the European Economic Community. France, West Germany, the Scandinavian countries, Republic of South Africa, Yugoslavia, and Czechoslovakia presented the principal competition. Ferroalloy imports from most of these countries were free of duty.[3]

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[2] Metal Bulletin (London). No. 4956, Dec. 15, 1964, p. 23.
[3] Metal Bulletin (London). No. 4918, July 31, 1964, p. 19.

TABLE 8.—U.S. imports for consumption of ferromanganese and ferrosilicon, by countries

Country	Ferromanganese (manganese content), excluding silicomanganese				Ferrosilicon (silicon content)			
	1963		1964		1963		1964	
	Short tons	Value	Short tons	Value	Short tons	Value	Short tons	Value
North America:								
Canada	--------	--------	2,503	$377,911	1,962	$667,616	2,014	$654,003
Mexico	1,094	$146,476	--------	--------	--------	--------	--------	--------
South America: Chile	6,491	1,257,584	4,375	782,300	--------	--------	--------	--------
Europe:								
Belgium-Luxembourg	6,764	1,020,077	25,066	3,189,193	--------	--------	--------	--------
France	32,791	5,030,875	30,161	4,143,601	102	17,326	31	5,629
Germany, West	36,724	4,767,124	16,528	2,328,689	5	4,850	54	59,714
Italy	353	82,000	1,284	299,728	17	2,959	42	11,823
Netherlands	--------	--------	467	59,843	--------	--------	--------	--------
Norway	--------	--------	--------	--------	290	51,014	857	145,898
Spain	5,307	672,800	7,385	841,615	--------	--------	--------	--------
Yugoslavia	173	21,796	--------	--------	--------	--------	--------	--------
Asia:								
India	2,196	278,298	56,001	10,941,727	--------	--------	1	284
Japan	7,263	1,631,828	4,160	999,033	--------	--------	45	30,498
Outer Mongolia	--------	--------	--------	--------	--------	--------	1	538
Africa:								
Mozambique	840	107,850	--------	--------	--------	--------	--------	--------
South Africa, Republic of	15,381	1,957,032	14,145	1,847,480	--------	--------	--------	--------
Total	115,377	16,973,740	162,075	25,811,120	2,376	743,765	3,045	908,387

Source: Bureau of the Census.

TABLE 9.—U.S. exports of ferroalloys

Alloy	1961		1962		1963		1964	
	Short tons	Value	Short tons	Value	Short tons	Value	Short tons	Value
Ferrochrome	7,844	$2,837,518	3,075	$1,182,382	2,354	$772,937	10,032	$2,504,405
Ferromanganese	469	146,178	4,114	629,401	678	154,973	3,903	670,073
Ferromolybdenum	179	501,476	95	305,126	120	379,173	873	3,328,494
Ferrophosphorus	32,860	1,425,568	14,130	594,666	41,361	1,302,337	163,166	4,938,385
Ferrosilicon	34,764	6,104,913	4,101	1,348,661	3,130	947,773	5,785	1,232,450
Ferrotitanium and ferro-carbon-titanium	212	93,389	130	95,265	211	182,828	541	391,771
Ferrotungsten	(1)	1,569	6	26,136	1	2,927	(1)	2,068
Ferrovanadium	120	436,208	201	745,912	183	587,690	103	308,880
Other ferroalloys	4,839	1,234,682	348	233,591	430	262,985	636	392,133
Spiegeleisen	525	46,617	715	59,275	1,176	89,766	785	59,446
Total	81,812	12,828,118	26,915	5,220,415	49,644	4,683,389	185,824	13,828,105

[1] Less than ½ unit.

Source: Bureau of the Census.

Japan.—The price of domestically produced ferroalloys to Japanese steel mills was approximately 20 percent higher than the price of alloys supplied by the Republic of South Africa. Japanese producers sent samples of 16 ferroalloy items to the Chinese People's Republic in anticipation of orders within the 1962 long-term private trade agreement.[4]

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[4] Mining Journal (London). V. 263, No. 6737, Oct. 2, 1964, p. 248.

Norway.—The market for Norwegian ferroalloys improved substantially in 1964 and resulted in a 23 percent increase in production. Production of ferrosilicon increased 42 percent.[5]

South Africa, Republic of.—In April, Palmiet Chrome Corp. (Pty.), Ltd. commissioned a second furnace at Krugersdorp. These ferrochromium operations are on a site provided by West Rand Consolidated Mines, Ltd. Two other ferrochromium plants started operating in 1964: RMB Alloys (Pty.), Ltd. (subsidiary of Rand Mines, Ltd.) at Middleburg, and Transalloys (Pty.), Ltd. (a joint venture of Anglo American Corporation of South Africa, Ltd., and the Swedish firm of Avesta Jernverks AB) at Witbank. Both are in the Transvaal east of Johannesburg, and will use South African chemical-grade ore. More than 95 percent of the ferrochromium produced by these two plants was expected to be for export.

Spain.—Ferroaleaciones y Electrometales S.A. (FYESA), producer of ferromanganese, silicomanganese, and ferrosilicon since 1961 at Boo, near Santander, began producing low-carbon ferrochromium. This was the first Spanish production of this alloy. Some high-carbon ferrochromium has been produced by Almuso and by Ferroaleaciones Espanolas.[6]

United Arab Republic (Egypt).—The appendix to the September 22, 1964, Economic and Technical Cooperation Agreement with the U.S.S.R. lists industrial ventures to be considered for construction or expansion. This list included a plant for production of ferrosilicon. Soviet contributions to the project, planned for an annual capacity of 20,000 tons, would include: Technical and economic feasibility studies, equipment, provision of Soviet specialists and training of Arab personnel.

United Kingdom.—The competitive positions of molybdenum, tungsten, vanadium, and columbium were accentuated by a tight-supply situation and some increase in price.

TECHNOLOGY

Early in 1964, Interlake Iron Corp. began commercial operation of its highly automated electric furnace at Beverly, Ohio. Interchangeable hearths, which can be changed in a matter of hours, permit changeover of products with a minimum of contamination and allow use of optimum hearth size for the different products. The entire hearth can be rotated slowly at a variable rate from 1 revolution every 8 hours to 1 revolution every 200 hours.[7]

Interlake Iron Corp. announced a new research center to be completed at Euclid, Ohio, to centralize research and development, expand technical service to customers, and broaden and improve product lines.

Ferrosilicon for use in heavy-media separation of ores is generally wet ground and dried, with some resulting decomposition. In a new development, a West German firm atomizes molten ferrosilicon with steam, the particles being then quenched in water, dried and screened.

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[5] Canadian Mining Journal (Gardenvale, Quebec). V. 86, No. 4, April 1956, p. 102.

[6] Metal Bulletin (London). No. 4907, June 23, 1964, p. 15.

[7] Iron and Steel Engineer. Giant Ferroalloy Furnace With Interchangeable Hearths Puts Interlake in Silicon Market. V. 61, No. 2, February 1964, pp. 137–141.

The resulting product is spherical in shape and shows no deterioration in composition. It is claimed that the spherical shape reduces adhesion losses in the heavy-media separation operation and reduces abrasion of pipes and pumps. Power requirements for operating the pumps are said to be lowered with possible savings up to 37.5 percent.[8]

A process, developed at the Avesta works in Sweden, was used to produce ferrochromium from ores of low chromium to iron ratio (1.5:1) at the Witbank, Republic of South Africa, plant of Trans-alloys (Pty.), Ltd., which began operations in May. In the process, selective reduction of the iron oxides of the melted ore is accomplished by addition of ferrosilicon chromium. The chromium-rich residue left after tapping off the resulting iron alloy has the chromium to iron ratio (3:1) of a metallurgical ore. This is processed by standard metallurgical methods to produce low-carbon ferrochromium. Trans-alloys is a joint venture of Anglo American Corp. of South Africa, Ltd., and Avesta Jernverks AB of Sweden. Initial annual capacity of the plant is 15,000 tons of low-carbon ferrochromium, 5,000 tons of high-carbon ferrochromium, and 1,000 tons of ferrochromium silicon. All products will be exported.[9]

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[8] New Scientist (London). V. 21, No. 383, Mar. 19, 1964, p. 748.

[9] South African Mining and Engineering Journal. V. 75, Pt. 1, No. 3718, May 8, 1964, p. 1019.

Fluorspar and Cryolite

By E. C. Peterson[1]

◆

FLUORSPAR

INCREASED DEMAND for fluorspar, principally in the hydrofluoric acid and steel industries, brought 1964 consumption to an unprecedented high.

A significant development during the year was the introduction of fluorspar pelletizing on a commercial basis. The product was used for flux in steelmaking, and it appears to have been well accepted by the steel industry.

TABLE 1.—Salient fluorspar statistics

	1955–59 (average)	1960	1961	1962	1963	1964
United States:						
Production:						
Crude:						
Mine production..short tons..	732,620	575, 700	615, 075	623, 750	586, 158	620, 474
Material milled or washed short tons..	698,120	558, 600	524, 400	586, 700	586, 400	624, 745
Beneficiated material recovered..............short tons..	280, 640	225, 900	185, 200	192, 000	188, 200	202, 300
Finished (shipments).......do....	288, 547	229, 782	197, 354	206, 026	[r] 199, 948	217, 137
Value..............thousands..	$13, 275	$10, 391	$8, 940	$9, 166	[r] $9, 001	$9, 723
Imports for consumption..short tons..	485, 651	534, 020	505, 759	595, 695	[r] 559, 653	687, 933
Value.................thousands..	$11, 788	$14, 393	$13, 644	$15, 596	[r] $14, 192	$16, 882
Exports...................short tons..	1, 269	458	338	1, 308	1, 202	3, 702
Value.................thousands..	$88	$38	$30	$119	$157	$158
Consumption.............short tons..	584, 102	643, 759	687, 940	652, 888	736, 350	898, 414
Stocks Dec. 31:						
Domestic mines:						
Crude.................do....	181, 155	137, 723	221, 961	277, 876	299, 197	299, 109
Finished.................do....	20, 002	16, 013	21, 001	14, 549	14, 954	10, 174
Consumer plants.............do....	184, 662	216, 330	188, 413	186, 772	181, 934	203, 014
Importers...................do....	48, 958	61, 578	75, 811	75, 303	68, 038	65, 116
World: Production..................do....	1, 885, 000	2, 230, 000	2, 275, 000	2, 365, 000	2, 340, 000	2, 770, 000

[r] Revised.

LEGISLATION AND GOVERNMENT PROGRAMS

The Office of Minerals Exploration (OME) continued its assistance for approved exploration projects for fluorspar. Government participation by OME in these projects was limited to 50 percent of approved costs, with $250,000 the maximum for any one contract. No exploration contracts for fluorspar were in force at the beginning of 1964, and none were executed during the year.

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[1] Commodity specialist, Division of Minerals.

TABLE 2.—Fluorspar in Government inventories as of Dec. 31, 1964

Grade	Objective	National (strategic) stockpile	DPA inventory	CCC and supplemental stocks
Acid grade	540,000	458,089	17,317	668,684
Metallurgical grade	850,000	369,443		42,800

DOMESTIC PRODUCTION

Shipments of finished fluorspar from 23 domestic mines totaled 217,000 short tons and comprised, by grade, 122,400 tons acid at $6,356,000, 47,700 tons ceramic at $2,028,000, and 47,000 tons metallurgical at $1,339,000. Fluorspar was produced in Colorado, Illinois, Kentucky, Montana, Nevada, New Mexico, and Utah. Illinois continued to be the leading producing State, supplying about 58 percent of the total production.

Domestic mines produced 620,474 tons of crude ore, an increase of 6 percent over that of 1963. Six mines produced over 20,000 tons each accounting for 92 percent of the total mine-run ore. At 12 independent and consumer-operated mills 624,745 tons of crude ore was processed from which 202,300 tons of finished fluorspar was recovered, including 166,073 tons of flotation concentrate. The remainder consisted of gravel and lump-sized fluorspar and material reclaimed from several mine dumps. During 1964, 11,984 tons of crude fluorspar was marketed as mined, compared with 12,441 tons of material in 1963.

In Kentucky, a new company, the Nancy Hanks Mining Co., was rehabilitating the old Nancy Hanks mine near Salem. The same company was planning to sink a new shaft on its Haffaw Tract at Mexico, Ky. Near Burna, Calvert City Chemical Co., the fluorspar producing subsidiary of Pennsalt Chemicals Corp., completed its heavy media separator preconcentrator at its Dyers Hill mine.

On March 1, in an effort to expand its domestic fluorspar market, The Minerva Co. placed into operation at its No. 1 mine near Cave-in-Rock., Ill., a commercial plant designed to produce fluorspar pellets. The facility was designed to produce, at the rate of 5 tons per hour, pellets ranging in size from ⅛ to 1 inch in diameter. The new product was designed specifically for use as a flux in steelmaking. The pellets were said to have the following advantages over fluorspar gravel normally used in steel production: Uniformity in size and composition, easy handling, low in fines and impurities such as zinc and sulfur, and a readily available domestic source of supply.[2]

The Ozark-Mahoning Mining Co. fluorspar operations were closed by a strike in July which continued through November. An announcement by the Aluminum Company of America indicated that its fluorspar mine near Rosiclare, Ill., would be closed in 1965; however, milling of stockpiled ore would continue.[3]

Arrangements for the Racon Inc. proposed fluorocarbon plant near Wichita, Kans., neared completion. Construction of the 15-million-pound per year fluorocarbon facility was expected to begin early in 1965, and completion has been set for late summer of the same year. The chemical process has been licensed from Daikin Kogyo Co., Japan.

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[2] Chemical & Engineering News. Fluorspar Pelletizing Ready to Start. V. 42, No. 10, Mar. 9, 1964, pp. 78–79.

[3] Montgomery, Gill. Fluorspar. Min. Eng., v. 17, No 2, February 1965, p. 125.

TABLE 3.—Shipments of finished fluorspar from domestic mines, by States

State	1963			1964		
	Short tons	Value		Short tons	Value	
		Total	Average per ton		Total	Average per ton
Illinois	132,060	$6,547,149	$49.58	127,454	$6,451,755	$50.62
Kentucky	35,072	1,537,327	43.83	38,214	1,692,997	44.30
New Mexico	------	------	------	137	3,014	22.00
Utah	247	6,700	27.13	(1)	(1)	(1)
Other [2]	[r] 32,569	[r] 910,832	[r] 27.97	51,332	1,575,635	30.69
Total	[r] 199,948	[r] 9,001,000	[r] 45.02	217,137	9,723,000	44.78

[r] Revised.
[1] Included with "Other" to avoid disclosing individual company confidential data.
[2] Includes Colorado, Montana, and Nevada to avoid disclosing individual company confidential data.

CONSUMPTION AND USES

Consumption of all grades of fluorspar reached a record 898,414 tons in 1964, an increase of about 22 percent over the previous high of 1963. The manufacture of hydrofluoric acid, a vital chemical used to produce synthetic cryolite and aluminum fluroide for the aluminum industry and the major source of fluorine for the chemical industry, continued to be the largest consumer and used more fluorspar than in any previous year. Increased consumption was also reported by the steel industry, where fluorspar was used as a flux in the making of basic open-hearth-, basic-oxygen-, and electric-furnace steel. Fluorspar consumption was reported in 37 States, but 6 States, Texas, Louisiana, Pennsylvania, Ohio, New Jersey, and Illinois, reported over half of the total consumption.

The National Aeronautics and Space Administration (NASA) planned to spend $40 million to develop and use a fluorine-oxygen fuel to launch the Atlas rocket. Initially, NASA announced an estimated consumption of fluorspar at 1,000 to 1,500 tons annually, but the quantity could be larger. It was reported that the addition of about 30 percent fluorine (approximately 57,000 pounds) to the oxidizer (liquid oxygen) of the Atlas rocket will significantly increase booster performance.[4]

Announcement was made of a new exterior house siding that is factory coated with polyvinyl fluoride (PVF) film. Reportedly, the siding offers excellent resistance to weather. It was estimated that manufacturers of the film used in the siding can aim for a market of 750 million square feet, or 11 million pounds per year.[5]

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[4] Oil, Paint and Drug Reporter. Fluorine Gets a Market as NASA Orders 2 to 3 Million Lbs. for Flox. V. 186, No. 1, July 6, 1964, p. 27.

[5] Chemical Engineering. Fluorine-Bearing Films Get Set For Bigger Markets. V. 71, No. 10, May 11, 1964, pp. 90–91.

TABLE 4.—Fluorspar shipped from mines in the United States, by types and uses

Type and use	1963				1964			
	Quantity		Value		Quantity		Value	
	Short tons	Percent of total	Total	Average per ton	Short tons	Percent of total	Total	Average per ton
Ground and flotation concentrates:								
Hydrofluoric acid	113,953	67.6	$5,924,092	$51.99	110,236	64.8	$5,841,564	$52.99
Glass	30,453	18.1	1,283,895	42.16	25,471	15.0	1,080,274	42.41
Ceramic and enamel	4,496	2.7	186,989	41.59	4,569	2.7	191,615	41.94
Nonferrous	2,687	1.6	114,589	42.65	2,129	1.2	92,453	43.43
Ferrous	11,650	6.9	469,265	40.28	22,268	13.1	947,855	42.57
Miscellaneous [1]	5,256	3.1	213,891	40.69	5,461	3.2	230,723	42.25
Total	168,495	100.0	8,192,000	48.62	170,134	100.0	8,384,000	49.28
Fluxing gravel and foundry lumps:								
Nonferrous	12	--------	480	40.00	12	--------	492	41.00
Ferrous	21,518	[r] 68.4	667,165	31.00	38,160	81.2	1,189,386	31 17
Miscellaneous	[r] 9,923	[r] 31.6	[r] 141,642	[r] 14.27	8,831	18.8	149,039	16.88
Total	[r] 31,453	100.0	[r] 809,000	[r] 25.72	47,003	100.0	1,339,000	28.49

[r] Revised.
[1] Includes exports.

TABLE 5.—Fluorspar (domestic and foreign) consumed and in stock in the United States, by grade and use

(Short tons)

Grade and use	1963		1964	
	Consumption	Stocks at consumer plants Dec. 31	Consumption	Stocks at consumer plants Dec. 31
Acid grade:				
Hydrofluoric acid	414,500	46,066	514,572	35,127
Glass	6,728	695	6,614	751
Enamel	399	63	325	51
Welding rod coatings	1,193	95	1,298	107
Nonferrous	(1)	(1)	(1)	(1)
Special flux Ferroalloys Primary aluminum	2,448	823	2,253	1,091
Total	425,268	47,742	525,062	37,127
Ceramic grade:				
Glass	24,334	3,221	23,462	2,702
Enamel	5,117	642	4,746	674
Welding rod coatings	2,550	268	3,003	183
Nonferrous	280	81	297	46
Special flux Ferroalloys	6,429	1,656	6,034	976
Total	38,710	5,868	37,542	4,581
Metallurgical grade:				
Glass	403	49	439	21
Enamel	—	—	—	—
Welding rod coatings	(2)	(2)	(2)	(2)
Nonferrous	10,292	2,540	10,952	1,751
Special flux Ferroalloys Primary magnesium	1,728	3,303	1,469	1,457
Iron foundry	17,125	4,776	18,066	4,232
Basic open-hearth steel	135,832	117,656	160,770	153,845
Basic oxygen steel	64,822		95,720	
Electric-furnace steel	42,170		48,394	
Total	272,372	128,324	335,810	161,306
All grades:				
Hydrofluoric acid	414,500	46,066	514,572	35,127
Glass	31,465	3,965	30,515	3,474
Enamel	5,516	705	5,071	725
Welding rod coatings	3,743	363	4,301	290
Nonferrous	10,572	2,621	11,249	1,797
Special flux	5,088	1,494	4,680	889
Ferroalloys	2,010	503	2,041	276
Primary aluminum Primary magnesium	3,507	3,785	3,035	2,359
Iron foundry	17,125	4,776	18,066	4,232
Basic open-hearth steel	135,832	117,656	160,770	153,845
Basic oxygen steel	64,822		95,720	
Electric-furnace steel	42,170		48,394	
Total	736,350	181,934	898,414	203,014

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[1] A small amount of acid grade is included with metallurgical grade to avoid disclosing individual company operations.

[2] Included with ceramic grade to avoid disclosing individual company confidential data.

TABLE 6.—Fluorspar consumption for different steelmaking processes

Process and consumption	1955–59 (average)	1960	1961	1962	1963	1964
Basic and acid open-hearth:						
Total............thousand short tons..	193	169	156	134	136	161
Per short tons of steel made........pounds..	4.2	4.0	3.8	3.2	3.3	3.3
Basic oxygen:						
Total............thousand short tons..	NA	NA	NA	46	65	96
Per short ton of steel made........pounds..	NA	NA	NA	16.8	17.6	12.6
Electric-furnace:						
Total............thousand short tons..	32	46	49	35	42	48
Per short ton of steel made........pounds..	8.0	11.6	11.9	r 8.2	r 8.4	8.2

r Revised. NA Not available.

TABLE 7.—Fluorspar (domestic and foreign) consumed in the United States, by States

(Short tons)

State	1963	1964
Alabama, Georgia, and North Carolina............	11,604	11,580
Arkansas, Kansas, Louisiana, Mississippi, and Oklahoma....	84,592	140,754
California and Hawaii............	30,195	32,618
Colorado and Utah............	21,221	23,606
Connecticut............	1,414	1,385
Delaware and New Jersey............	133,695	121,464
Florida, Rhode Island, and Virginia............	1,131	1,371
Illinois............	47,597	54,972
Indiana............	27,573	26,720
Iowa, Minnesota, Nebraska, South Dakota[1], and Wisconsin............	3,857	5,041
Kentucky............	41,183	41,535
Maryland............	8,257	9,505
Massachusetts............	163	242
Michigan............	40,328	50,813
Missouri............	2,313	3,000
New York............	14,114	16,623
Ohio............	65,198	76,911
Oregon and Washington............	1,477	1,616
Pennsylvania............	64,898	83,195
Tennessee............	2,600	2,666
Texas............	89,529	144,488
West Virginia............	43,411	48,309
Total............	736,350	898,414

[1] 1963 only.

TABLE 8.—Stocks of fluorspar at mines or shipping points in the United States, by States, Dec. 31

(Short tons)

State	1963		1964	
	Crude	Finished	Crude	Finished
Illinois............	273,972	11,370	281,490	6,276
Kentucky............	2,397	37	558	------
Colorado, Montana, Nevada, and Utah............	22,828	3,547	17,061	3,898
Total............	299,197	14,954	299,109	10,174

PRICES

The following are beginning and yearend prices or ranges of prices of some principal fluorspar grades, as reported in the E&MJ Metal and Mineral Market in 1964:

	Per short ton	
	January 1964	*December 1964*
Domestic:		
Metallurgical grade, 72½ percent, effective CaF_2, f.o.b. Illinois	$37.00 to $39.00	$37.00 to $39.00
Acid grade concentrates, dry basis, 97 percent CaF_2, f.o.b. Illinois, carloads	45.00	45.00
Less than carloads, Illinois	50.00	50.00
Bags, extra	3.00	3.00
Ceramic grade, 95 percent CaF_2	43.00	43.00
European:		
Metallurgical grade, 72½ percent effective CaF_2, duty paid	30.00 to 33.00	30.00 to 33.00
Mexican:		
Metallurgical grade, 72½ percent, effective CaF_2:		
Border, all rail, duty paid	24.50 to 26.00	29.70
Brownsville, Tex., barge, duty paid	27.00 to 28.50	32.50
Tampico, Mexico, vessel cargo lots	17.00 to 19.00	22.50
U.S. Atlantic ports, cars, duty paid	31.00 to 34.00	35.50

FOREIGN TRADE

Fluorspar imports for consumption increased 23 percent over that in 1963. Mexico supplied 80 percent of the total.

Fluorspar containing more than 97 percent CaF_2 was subject to a duty of $1.875 per short ton ($2.10 per long ton), and that containing not more than 97 percent CaF_2 was dutiable at $7.50 per short ton ($8.40 per long ton).

Of exports totaling 3,702 tons, Canada received 3,575 tons and the remainder was shipped to Mexico, Venezuela, Uruguay, Colombia, Panama, the Republic of South Africa, the United Kingdom, the Federal Republic of Germany, and Switzerland.

TABLE 9.—U.S. imports for consumption of fluorspar, by countries and customs districts

Country and customs district	1963				1964			
	Containing more than 97 percent calcium fluoride		Containing not more than 97 percent calcium fluoride		Containing more than 97 percent calcium fluoride		Containing not more than 97 percent calcium fluoride	
	Short tons	Value	Short tons	Value	Short tons	Value	Short tons	Value
Canada:								
Buffalo							9,895	$214,228
El Paso			69	$1,389				
Laredo							1,064	21,464
Washington	4	$140						
Total	4	140	69	1,389			10,959	235,692
Greenland: Laredo							1,195	24,108
Guatemala: El Paso					42	$1,062		
Mexico:								
Arizona							45	901
Buffalo			7,354	123,003			2,746	63,720
Dakota							21	433
El Paso	69,630	1,652,974	40,420	808,124	58,955	1,426,842	59,530	1,191,042
Galveston	432	13,812			831	26,621		
Kentucky					310	7,762		
Laredo	135,754	4,003,566	78,876	1,566,334	162,556	4,506,767	116,769	2,288,305
Los Angeles	172	4,314	100	2,003				
Maryland			6,608	110,450			4,604	85,753
Massachusetts			20	393				
Michigan			r 19,379	r 365,681	7,634	260,178	36,021	831,267
Mobile			8,053	124,590				
New Orleans	17,805	567,383	16,551	295,422	28,678	1,032,234	41,533	873,613
New York			40	1,015				
Ohio			11,638	245,484			4,684	103,079
Philadelphia	27,801	956,549	7,225	123,154	12,430	364,109	13,977	297,990
St. Louis					833	18,828		
San Diego	78	2,419						
Vermont			128	2,548				
Total	251,672	7,201,017	r 196,392	r 3,768,201	272,227	7,643,341	279,930	5,736,103
Colombia:								
El Paso	9	228						
Galveston					306	9,863		

France:								
Michigan	6,160	121,185						
New Orleans	3,388	86,063						
Philadelphia					22	1,049		
Total	9,548	207,248			22	1,049		
Germany, West: Puerto Rico	399	25,075			299	20,505		
Italy:								
New Orleans	22,873	771,290			12,164	364,248		
Philadelphia	10,201	307,410			26,303	695,988		
Total	33,074	1,078,700			38,467	1,060,236		
Spain:								
New Orleans					5,962	161,738		
Ohio	25,317	703,050			22,472	561,974		
Philadelphia	43,006	1,203,209			56,052	1,426,789		
Total	68,323	1,906,259			84,486	2,150,501		
United Kingdom:								
El Paso	129	3,207	34	661				
Puerto Rico								
Total	129	3,207	34	661				
Grand total	363,158	10,421,874	r 196,495	r 3,770,251	395,849	10,886,557	292,084	5,995,903

r Revised.

Source: Bureau of the Census.

TABLE 10.—Imported fluorspar delivered to consumers in the United States, by uses

Use	1963			1964		
	Short tons	Selling prices at tidewater, border, or f.o.b. mill in the United States including duty		Short tons	Selling prices at tidewater, border, or f.o.b. mill in the United States including duty	
		Total	Average per ton		Total	Average per ton
Hydrofluoric acid	77, 865	$2, 288, 709	$29. 39	203, 152	$7, 075, 102	$34. 83
Glass, ceramic, and enamel	4, 252	138, 510	32. 58	7, 219	355, 221	49. 20
Ferrous	85, 400	2, 103, 251	24. 63	104, 373	2, 519, 001	24. 13
Nonferrous	232	7, 097	30. 59	2, 447	61, 082	24. 96
Other	54, 587	1, 517, 279	27. 80	56, 669	1, 872, 751	33. 05
Total	222, 336	6, 054, 846	27. 23	373, 860	11, 883, 157	31. 79

TABLE 11.—U.S. exports of fluorspar

Year	Short tons	Value	Year	Short tons	Value
1955-59 (average)	1, 269	$87, 510	1962	1, 308	$118, 749
1960	458	38, 250	1963	1, 202	156, 898
1961	338	30, 419	1964	3, 702	158, 099

Source: Bureau of the Census.

WORLD REVIEW

NORTH AMERICA

Canada.—In 1963 fluorspar production was valued at more than $2 million, the highest since 1956. Almost the entire production was from Newfoundland, with a few tons produced in British Columbia.

Imports, mainly from Mexico, were valued at $1.9 million. Most was consumed in steel production and in metallurgical and foundry processes.

Huntington Fluorspar Mines Ltd. manufactured a 5-pound fluorspar briquet using imported metallurgical-grade fluorspar at a new plant at Northbrook, Ont. The briquet were marketed exclusively for foundry use.[6]

A $400,000 plant was planned by the Electric Reduction Co. of Canada at Port Maitland, Ontario, to produce fluorides for municipal water supplies. The capacity of the plant is sufficient to provide Canada with most of its fluoride chemicals for the foreseeable future.[7]

Mexico.—The Soviet Union purchased 35,000 tons of fluorspar from Mexico and was negotiating for more purchases in 1965 and 1966. Mexico may be replacing China as a source of fluorspar.[8]

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[6] Bartley, C. M. Fluorspar. Dept. Mines and Tech. Surveys, Ottawa, Canada, Mineral Proc. Div. Mines Branch, 1963, 7 pp.

[7] Chemical Age (London). Canadian Plant for Fluoridation Chemicals. V. 92, No. 2361, Oct. 10, 1964, p. 566.

[8] Chemical Week. V. 95, No. 10, Sept. 5, 1964, p. 51.

TABLE 12.—World production of fluorspar by countries [1] [2]

(Short tons)

Country [1]	1955–59 (average)	1960	1961	1962	1963	1964 [p]
North America:						
Canada	94,026	[e] 77,000	[e] 80,000	[e] 75,000	[e] 85,000	[e] 95,000
Mexico	368,291	404,487	439,286	553,642	530,893	687,917
United States (shipments)	288,547	229,782	197,354	206,026	199,948	217,137
South America: Argentina	13,961	13,748	11,105	9,976	9,711	6,855
Europe:						
France	105,218	149,345	214,936	154,064	160,307	242,508
Germany:						
East [e]	77,160	80,000	80,000	80,000	80,000	80,000
West (marketable)	150,889	143,474	133.515	116,592	95,843	86,098
Italy	149,256	178,957	172,582	171,474	137,232	136,723
Spain (marketable)	90,086	122,377	161,954	165,356	169,094	161,135
Sweden (sales)	2,317	3,212	3,542	3,900	3,307	[3] 3,307
United Kingdom [4]	96,602	109,249	99,868	79,525	84,878	[e] 171,960
Asia:						
China [e]	158,700	275,000	220,000	220,000	220,000	220,000
Japan	6,989	10,108	16,326	17,120	23,037	20,979
Korea:						
North [e]	33,000	33,000	33,000	33,000	33,000	33,000
South	5,743	20,834	30,790	36,343	43,855	62,167
Mongolia	30,800	44,400	42,000	41,800	[e] 55,000	[e] 62,800
Thailand	----------	3,814	5,241	11,806	32,221	70,039
Turkey	37	359	42	640	719	1,436
U.S.S.R. [e] [5]	165,000	210,000	230,000	265,000	300,000	330,000
Africa:						
Morocco	37	----------	869	546	7,000	7,242
Rhodesia (formerly Southern)	306	19	----------	20	343	77
South Africa, Republic of	44,316	113,550	95,862	111,683	57,761	66,431
South-West Africa	169	----------	----------	240	480	----------
Oceania: Australia	701	8	----------	----------	17	----------
World total (estimate) [1] [2]	1,885,000	2,230,000	2,275,000	2,365,000	2,340,000	2,770,000

[e] Estimate. [p] Preliminary.

[1] Fluorspar is also produced in Bulgaria, data not available; estimate included in total.

[2] This table incorporates some revisions. Data do not add exactly to totals shown because of rounding where estimated figures are included in the detail.

[3] 1963 data.

[4] Includes fluorspar recovered from old lead and zinc mine dumps, production of which is reported as follows: 1955–59 (average), 10,617 tons; 1960, 13,552 tons; 1961–64, data not available.

[5] U.S.S.R. in Europe included with U.S.S.R. in Asia, as the deposits are predominantly in Asiatic U.S.S.R.

TABLE 13.—International fluorspar trade in 1963

(Short tons)

Producing country	Exports	Principal destination
Canada	3,012	United States 3,007.
China	[1] 123,399	Asia 56,675; Eastern Europe 56,328; Western Europe 10,363.
France	51,337	United States 15,056; Western Europe 36,209; Africa 72.
Germany:		
East	[2] 17,043	Eastern Europe 12,346; Western Europe 4,697.
West	12,785	Western Europe 12,377; South America 108; United States 300.
Italy	42,184	United States 38,311; Western Europe 3,873.
Korea:		
North	[2] 3,276	All to Asia.
South	35,159	Asia, Japan 33,973; Asia, other 1,186.
Mexico	562,475	United States 475,955; Canada 85,677; Western Europe 555; South America 162; Asia 126.
Mongolia	[1] 51,919	All to Eastern Europe.
Morocco	1,679	All to Western Europe.
Spain	95,465	United States 68,892; Western Europe 25,289; Asia, Japan 926; Asia, other 357.
South Africa, Republic of	63,356	Asia 37,255; Canada 9,600; Western Europe 7,404; Africa 4,996; Australia 3,221; South America 840.
United States	1,202	Canada 726; South America 376; Western Europe 18; Asia, other 82.
U.S.S.R.	[2] 3,638	Asia 3,638.

[1] Imports.

[2] Incomplete data.

EUROPE

Austria.—Aluminum fluoride was being manufactured from hydrofluosilicic acid at the rate of 12,000 tons per year at the Oesterreichische Stickstoffwerke A.G. plant at Linz, Austria. Normally this fluoride is produced from hydrofluoric acid, but the method, developed by the Austrian company, not only produces the fluoride at a lower cost but also makes available a much greater amount of fluorine-containing raw material for the process.[9]

Finland.—A phosphoric acid concentration unit and fluorine recovery plant for the production of a wide range of fluosilicates was being constructed in Finland. The plant, designed, engineered, and supervised by L. A. Mitchell, Ltd., will have a capacity of 30,000 tons per year of phosphoric acid and was expected to be in operation during 1965.

Germany, Federal Republic of.—There was a continued decline in the output of acid-grade fluorspar and increased imports from Italy, Spain, and the Republic of South Africa. Near Nabburg, Bavaria, two fluorspar mines were closed. Gewerkschaft Finstergrund continued to operate the largest West German fluorspar mine, Utzenfeld, in the Black Forest. The reserve was estimated to be 1 million tons of fluoride-barite ore.

Hungary.—Synthetic cryolite, made from Hungarian raw materials, was being produced at the Magyaróvár alumina and synthetic corundum plant near the Australian border. Annual capacity at the plant when in full production will be 1,500 to 1,800 tons. A second plant with an annual capacity of 3,000 tons was planned as part of the new chemical combine at Szlonok in central Hungary.

Italy.—A joint company consisting of Montefluoro Prelapina SpA and Harvey Aluminum Inc. was being formed to produce hydrofluoric acid and synthetic cryolite for the Italian market. Montefluoro was the largest Italian producer of fluorspar from its mines in Trentino.

Start-up of a new fluorspar mine owned by SpA Sarramin-Sarrabus Mineraria near Cagliari, Sardinia, was expected early in 1965. The overall capacity of the installation, was expected to be 75,000 tons per year. The finished ore will be transported by 20- to 25-ton trucks to harbors at Cagliari and San Antioco for export.[10]

Netherlands.—A plant to produce fluorocarbons and hydrofluoric acid was being constructed at Budel. Plans called for an initial annual capacity of 10,000 tons of fluorocarbons and 5,000 tons hydrofluoric acid. Completion date was expected to be sometime in 1966.

Spain.—Belgium mining interests have shown considerable interest in recently discovered fluorspar deposits in the Camp de Caso, Asturia, area of Spain. The deposits were reported to be large and to contain over 98 percent CaF_2.

A company comprised of Belgium and West German interests announced that it would construct a new fluorocarbon facility near Santander in northern Spain. Start-up of the new plant is expected to be early in 1966.[11]

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[9] Chemical Trade Journal and Chemical Engineer (London). Austrian Development in Manufacture of Aluminium Fluoride. V. 154, No. 4016, May 29, 1964, p. 789.

[10] European Chemical News (London). Sardinian Fluoride Plant on Stream Soon. V. 6, No. 149, Nov. 20, 1964, p. 20.

United Kingdom.—A fluorspar mine with a large enough reserve to last 20 years was opened during 1964 by Glebe Mines, Ltd. The operations were in Derbyshire, about 2 miles from Glebe's existing Ladywash mine and about 1 mile from a flotation plant.

A high-grade fluorspar deposit was being mined by the Clay Cross Co. near Pateley Bridge, west Yorkshire. Currently, two methods of mining were used—underground mining of small lenses of fluorspar and the reworking of old tailing-dumps that occur on the property. The mined material contains over 90 percent CaF_2 and usually does not require further treatment.[12]

U.S.S.R.—The first fluorspar concentrate was produced at a processing plant in the southern part of the Far Eastern seaboard area of the Soviet Union. Production from this facility was to supply a cryolite plant in the Urals and various steel plants in the area.

ASIA

India.—Mafatlal Fine Spinning and Manufacturing Co., Ltd., was constructing a fluorochemical plant near Surat in the State of Gujarat. The project costing $1.3 million was to be completed in 1966. Fluorspar was to be imported; however, deposits found near Baroda, Gujarat State, were to be developed by the Gujarat State Mineral Development Corporation, and the Mafatlal Co., for future utilization.

Israel.—A fluoride salts plant was being constructed by Chemicals and Phosphates Ltd. of Israel, and it was expected to be completed by the end of the year. No output capacity of the plant has been announced.

AFRICA

Morocco.—The only fluorspar mine at El Hammam, was operated by S.A. des Enterprises Minieres.

South Africa, Republic of.—The Buffalo Fluorspar Mine of Frank Martin & Co. (Pty.) Ltd., near Naboomspruit, Transvaal, was acquired by General Mining Group. The plant has been modernized and reportedly was to be expanded. The proved fluorspar reserve available for open-pin mining was estimated to be 4 million tons.[13]

Tunisia.—A fluorspar mine at Hammam Zriba, Tunisia, was to be reopened in 1965 after being closed for more than 10 years. Estimated daily production was to be 150 tons.

TECHNOLOGY

The Bureau of Mines completed beneficiation studies on the recovery of fluorspar and barite from a complex ferruginous barite-fluorspar Tennessee ore. The crude ore contained 49.3 percent CaF_2 and 36.9 percent $BaSO_4$. Batch flotation tests, using a sodium fluoride, lignin sulfonate, and oleic acid combination to float the fluorspar and a sodium silicate, barium chloride, and petroleum sulfonate to float the barite from the fluorspar tailings, produced concentrate analyzing 98.3 percent CaF_2 with an 93-percent recovery, and barite concentrate containing 95 percent $BaSO_4$ with a recovery of about 74 percent. By comparison, when the barite was floated first, using the same reagents in reverse order, the barite concentrate produced analyzed 98.5 percent $BaSO_4$ with a recovery of about 70 percent, and fluorspar concentrate containing 99.5 percent CaF_2 with an 84-percent recovery. Continuous flotation tests of the fluorspar from the ore yielded concentrates that analyzed 98.3 percent CaF_2 with a recovery of 91 percent. Flotation of the barite from the fluorspar tailing gave concentrates that analyzed 91.2 percent $BaSO_4$ and accounted for a barite recovery of 85 percent.[14]

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[11] European Chemical News (London). Solvay to build Spanish fluorocarbons unit. V. 6, No. 149, Nov. 20, 1964, p. 22.

[12] Mine & Quarry Engineering (London). New Mill at Greenhow Hill. V. 30, No. 5, May 1964, pp. 221–222.

[13] Bureau of Mines. Mineral Trade Notes. V. 59, No. 5, November 1964, pp. 24–26.

Certain time determinations and structural projections relate the Illinois-Kentucky fluorspar district deformation to igneous and tectonic activity of the Mississippian Embayment province. A paper was published taking into recognition this relationship and suggesting that the more sharply defined genetic processes of the fluorspar deposits in the area may be applied to problems of ore genesis of other Mississippi Valley provinces.[15]

Recent experimental field operations conducted in southern Illinois by the Illinois State Geological Survey have indicated that the best application of the refraction seismic method in fluorspar exploration is the extension of faults from sites proven by previous drilling.[16]

Data on the types and qualities of fluorocarbon plastics were presented.[17]

Announcement was made of a new dry lubricant consisting of a fluorocarbon film, suitable for both metallic and nonmetallic surfaces. It can be easily applied by aerosol pressure and is dirt repellent, acting as an anti-stick, nonstaining, transparent, and repellent to chemicals, solvents, oils, and water.[18]

Soviet engineers have developed an antifriction material that is chemically stable and may be used at loads to about 500 pounds per square inch without lubrication. The material is a combination of TFE (Polytetrafluoroethylene) fluorocarbon plastic, quartz sand, and andesite. The compound is said to have the same chemical properties as TFE plastic, but, unlike TFE, it will form a highly adhesive antifriction coating on metal, ceramics, and wood.[19]

The first example of a partially fluorinated neutral boron hydride has been synthesized. Boron hydrides are of interest because they are useful as reducing agents in organic and inorganic chemistry and potentially useful as chemical fuels or fuel additives. Work is being extended into the synthesis of other fluorinated hydrides and the reactions and spectroscopid properties of this class of compounds.[20]

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[14] Eddy, W. H., and James S. Browning. Selective Flotation of a Barite-Fluorspar Ore From Tennessee. BuMines Rept. of Inv. 6491, 1964, 8 pp.

[15] Brecke, E. A. A Possible Source of Solutions of the Illinois-Kentucky Fluorspar District. Econ. Geol., v. 59, No. 7, November 1964, pp. 1293–1297.

[16] Johnson, Robert B. Seismic Method Tested in Illinois Fluorspar District. Mining Eng., v. 16, No. 1, January 1964, pp. 55, 56.

[17] Materials in Design Engineering. Fluorocarbon Plastics. V. 50, No. 2, February 1964, pp. 93–104.

[18] Light Metals. Dry Lubricant. V. 27, No. 309, February 1964, p. 42.

[19] Product Engineering. Developments To Watch. V. 35, No. 19, Sept. 14, 1964, pp. 39–40.

Researchers have synthesized fluorine-containing compounds designed to protect organic coatings against ultraviolet radiation. These compounds are said to be less volatile and to give better protection than presently available ultraviolet absorbers. Work on these materials, which was sponsored by the Air Force, stemmed from an interest in finding suitable additives for coatings used in missile and space applications.[21]

Copolymers of vinylidine fluoride and hexafluoropropylene represent one class of high-strength elastomers possessing heat and compression set-in resistance characteristics that make them applicable at temperatures from 400° to 600° F. An article in a recent publication describes the techniques in the manufacture of these elastomers for use as seals, gaskets, rolls, valves, and tank linings for use in the aircraft, missile, automotive, and chemical industries.[22]

An acid-type liquid, containing fluoride, phenolic compounds, and chlorinated hydrocarbons, has been developed. The liquid will remove epoxy, polyurethane, acrylic, vinyl, alkyd, and other inert finishes, as well as thin primer films from aluminum, magnesium, titanium, and steel parts. The stripping usually takes less than 30 minutes at ambient temperatures.[23]

A patent was granted relating to the method of producing hydrogen fluoride from fluorspar by precalcining the fluorspar. Increased plant capacity and lower maintenance costs are the chief benefits derived.[24]

A new rubber, featuring fluorine as a component, has been developed by a European chemical producer. The rubber is said to be particularly resistant to high temperatures and to chemicals.[25]

A fluorine-hydrogen rocket generating 40,000 pounds of thrust has been successfully fired. It was reported that combustion efficiency exceeded 95 percent.[26]

Fluorinated silicones were being investigated by LOX-resistant lubricating fluids for tube pumps, turbines, and gear boxes of aerospace vehicles. Some possibilities existed for their use as fire-resistant hydraulic fluids.[27]

Hydrogen fluoride and an alkali metal aluminate can be made from low-grade siliceous fluorspar or fluorine-containing material from the processing of phosphate rock by heating the fluorine containing material, high silica bauxites, and soda ash above 1,000° C in the presence of water vapor. Hydrogen fluoride, sodium aluminate, and dicalcium silicate are formed. In the process high silica aids the reaction.[28]

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[20] U.S. Department of Commerce. NBS Chemists Synthesize Fluorinated Boron Hydride. Technical News Bulletin, v. 48, No. 6, June 1964, p. 87.

[21] Chemical Engineering. Fluorine-Containing Organics Can Protect Against Ultraviolet Radiation. V. 71, No. 4, Feb. 17, 1964, pp. 47, 49.

[22] Industrial and Engineering Chemistry. Processing and Fabrication Fluid-Resistant Fluorocarbon Elastomers. V. 3, No. 1, March 1964, pp. 61–67.

[23] Materials in Design Engineering. Compound Removes Paint From Metal Parts. V. 60, No. 6, November 1964, p. 132.

[24] Hayworth, C. B., R. J. Hutzler, A. W. Michener, Jr., and R. Sobel (assigned to Allied Chemical Corp., New York). Process for the Production of Hydrogen Fluoride and Calcium Sulfate. U.S. Pat. 3,160,473, Dec. 8, 1964.

[25] Oil, Paint and Drug Reporter. Fluorine-Containing Rubber Is Developed by Montecatini. V. 186, No. 26, Dec. 28, 1964, p. 5.

[26] Chemical and Engineering News. A Fluorine-Hydrogen Rocket Generating 40,000 Pounds of Thrust. V. 42, No. 4, Apr. 6, 1964, p. 39.

[27] Adamczak, Robert L., Robert J. Benzing, and Herbert Schwenker. Advanced Lubricants and Lubrication Techniques. Ind. and Eng. Chem.. v. 56. No. 1. January 1964, pp. 40–47.

A ceramic-filled fluorocarbon tape, called Fluorosint, is now being marketed. The manufacturer states that the tape has excellent wear characteristics, low coefficient of friction, and exhibits minimum change in material dimensions and properties at temperatures ranging from minus 65° to 125° F. The Boeing 727 jet airliner uses the tape both as a seal and bearing surface in the horizontal stabilizer section of the aircraft.[29]

The development of a new grade of FFE fluorocarbon is expected to permit processors to mold a more complete range of products. The new material lends itself to isotatic molding techniques. Potential products are gears, mechanical components, and other complex parts.[30]

A West German chemist has found that if fluorine is used in a tungsten filament light bulb, the glass does not blacken, hot spots do not develop, and luminous efficiency is increased. Furthermore, bulb life would no longer depend on evaporation rate of the filament.[31]

A new toothpaste additive which may be more effective than stannous fluoride as a decay preventing agent has been developed by scientists at Indiana University's dental school. It was reported that the additive forms an almost completely insoluble reaction product with tooth enamel and is less expensive than stannous fluoride.[32]

A lubricant coating composition for reducing friction on space vehicles, composed of about 75 percent fluorspar and 25 percent ceramic binder, was patented.[33]

CRYOLITE

Mining was stopped in 1963 at Ivigtut, Greenland, the only commercial source of cryolite, due to the depletion of the deposit. Cryolite had been mined for about 100 years. Stockpiled material at the mine site was sufficient to supply consumer needs for the next 15 to 25 years.

Natural cryolite from Greenland was imported into the United States in crude form and processed by the only importer, The Pennsalt Chemicals Corp., at its Natrona, Pa., flotation mill.

Synthetic cryolite was produced by Kaiser Aluminum & Chemical Corp. at Chalmette, La. and by Reynolds Metals Co. at Bauxite, Ark. Cryolite was reclaimed from scrapped pot linings by Aluminum Company of America at Point Comfort, Tex.; by Kaiser Aluminum & Chemical Corp. at Chalmette, La., and Spokane, Wash.; and by Reynolds Metals Co. at Listerhill, Ala., Longview, Wash., Corpus Christi, Tex., Troutsdale, Oreg., Massena, N.Y., and Gum Spring, Ark.

During the year, the sale of 16,545 short tons of synthetic cryolite from the Defense Production Act Inventory was made for $2,524,775. This sale completely exhausted the Government synthetic cryolite stockpile. The supply has been declared surplus to Government requirements and was eligible for disposal as a nonstrategic item.

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[28] Chemical & Engineering News. A Process to Make Sodium Aluminate for Alumina and Hydrogen Fluoride. V. 42, No. 29, July 20, 1964, p. 35.

[29] Materials in Design Engineering. Fluorocarbon Tape Serves as Seal and Bearing. V. 59, No. 5, May 1964, pp. 132, 134, 144.

[30] Iron Age. Molding of Fluorocarbon. V. 193, No. 23, June 4, 1964, p. 15.

[31] Chemistry. Longer-Lasting Light Bulbs. V. 37, No. 11, November 1964, pp. 24, 25.

[32] Chemical & Engineering News. A New Toothpaste Additive. V. 42, No. 42, Oct. 19, 1964, p. 19.

[33] Sliney, H. E. (assigned to Administrator of National Aeronautics & Space Administration). Bonded Solid Lubricant Coating. U.S. Pat. 3,157,529, Nov. 17, 1964.

Stenonite, a new carbonate-fluoride mineral, was reported to have been found at the cryolite mine near Ivigtut, Greenland. The mineral occurs in the cryolite as small grains up to 1 x 4 centimeters in size. It is colorless to white with a vitreous luster, has a hardness of 3.5 Mohs, and specific gravity of 3.86. Stenonite was named after Nicholaus Stenonis, discoverer of the law of constancy of interfacial crystal angles.[34]

An improved process for recovering, in the form of cryolite, the fluorine contained in the gases and entrained dust resulting from the electrolytic production of aluminum was described in a patent.[35]

PRICES

Prices of cryolite remained unchanged from previous years. The Oil, Paint and Drug Reporter quoted the following prices for cryolite in 1964: Cryolite, natural, industrial, in bags, carlots, at works, 100 pounds, $13; and in bags, less than carlots, at works, 100 pounds, $14.25.

FOREIGN TRADE

The import statistics shown in table 14 do not distinguish between natural and synthetic cryolite, but it is believed that virtually all of the shipments from countries other than Greenland were synthetic cryolite. Exports of cryolite in 1964 totaled 3,385 tons valued at $743,795. Most of the exports went to Australia, Mexico, and Canada, smaller quantities being shipped to Argentina, the Republic of South Africa, Viet-Nam, the United Kingdom, Kenya, and Belgium-Luxembourg.

TABLE 14.—U.S. imports for consumption of cryolite

Year and country	Short tons	Value	Year and country	Short tons	Value
1961	13,814	$1,193,840	1964:		
1962	12,472	933,011	North America:		
			Greenland [1]	18,531	$727,675
1963:					
North America:			Europe:		
Canada	2	515	Germany, West	66	21,284
Greenland [1]	21,412	837,863	Italy	5,645	1,011 060
			Netherlands	22	4,932
Europe:					
Germany, West	44	14,118	Total	24,264	1,764,951
Italy	5,457	955,233			
Total	26,915	1,807,729			

[1] Crude natural cryolite.

Source: Bureau of the Census.

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[34] Mineralogist. Stenonite. V. 32, No. 2, April 1964, p. 36.

[35] Berthoux, Jean, Paul Mollard, and Roger Papp (assigned to Societe d'Electro-Chimie, d'Electro-Metallurgie et des Acieries Electriques d'Ugine, Paris, France). Process for Production of Cryolite From Fluorinated Compounds in Gases. U.S. Pat. 3,132,921, Feb. 20, 1962.

Gem Stones

By Benjamin Petkof[1]

⁂

ESTIMATE of 1964 production of gem materials and mineral specimens reached $1.5 million, an increase of 7 percent over 1963. Individual collectors continued to account for the bulk of domestic production.

Regulations controlling the collection of petrified wood on public lands were issued by the Bureau of Land Management of the Department of the Interior.[2]

DOMESTIC PRODUCTION

The Bureau of Mines discontinued its collection of data by direct canvass of known amateur and professional gem stone producers. Estimates of production indicated that 38 States produced gem stone. Of these, California, Oregon, Texas, Arizona, and Wyoming were the leading producers.

A deposit of black jade was discovered 62 miles southwest of Douglas, Wyo., by a rock hobbyist who leased his claim to the Eloxite Corp. Similar jade is known only in Siberia. The domestic stone is claimed to be of a better quality because it polishes to a more lustrous sheen. The mining company was selling the material for $8,000 per ton. Material has been shipped to Japan for cutting and carving and to the Federal Republic of Germany for jewelry.

The California Division of Mines and Geology announced the discovery of nephrite jade in 1962 by its personnel in the Bagby district 2½ N.-N.E. of Bagby, Calif. The jade occurs in veins along the east contact of the serpentine belt and ranges up to 5 feet thick and 150 feet long. The best quality jade occurs in various shades of green without any flaws and changes into rock of less desirable color perfection and hardness. The jade is generally within a thick shell of partially nephritized serpentine.[3]

The Himalaya Mine of San Diego County, Calif., which won its fame as a producer of gem tourmaline between 1903 and 1913, was sold to new owners who plan to open it for organized groups to hunt for tourmaline and other minerals that can be found on the mine dump.

A ruby weighing almost 87 carats was found at the old Shuler corundum mine in Cowee Valley near Franklin, N.C. The stone was valued in excess of $4,000.

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[1] Commodity specialist, Division of Minerals.

[2] Bureau of Land Management, U.S. Department of the Interior. Subchapter C—Minerals Management. Circ. 2147, July 1, 1964, pp. 5–6.

[3] California Mineral Information Service, Division of Mines and Geology. New Jade Deposit Found by Division . . . . V. 17, No. 2, February 1964, p. 21.

CONSUMPTION

Consumption of gem diamond reached $259 million, an increase of almost 16 percent over 1963; imported imitation and synthetic gem stones including imitation pearl was $6.1 million, an increase of 20 percent over 1963; and natural and cultured pearls were $19.7 million, an increase of 10 percent over 1963.

Apparent consumption (domestic production plus imports minus exports and reexports) of gem material in the United States was $189 million, up 11 percent over 1963.

PRICES

Prices quoted during the year for cut and polished, unmounted gem diamonds were 0.25 carat, $70 to $275; 0.50 carat, $185 to $600; 1 carat, $500 to $1,800; 2 carat, $1,200 to $5,600.

FOREIGN TRADE

Over 90 percent of the cut but unset emerald was imported from India. Nineteen other countries supplied the remaining quantity. The average value of emerald imports from India was $11.50 per carat.

Japan supplied the bulk of the pearl imports. Cut but unset rubies and sapphires, valued at $4.1 million, were imported. In addition, about $6.9 million of other precious and semiprecious stones were imported. However, no classification information on the latter was available.

TABLE 1.—U.S. imports for consumption of precious and semiprecious stones, exclusive of industrial diamonds

Stones	1963		1964	
	Quantity	Value (thousands)	Quantity	Value (thousands)
Diamonds:				
Rough or uncut, suitable for cutting into gem stones, duty-free carats	1,749,641	$129,870	1,547,955	$149,729
Cut but unset, suitable for jewelry, dutiable carats	1,071,620	93,977	1,096,795	108,805
Emeralds: Cut but not set, dutiable do	190,933	2,081	180,069	3,218
Pearls and parts, not strung or set, dutiable:				
Natural	(1)	479	(1)	474
Cultured or cultivated	(1)	17,427	(1)	19,204
Other precious and semiprecious stones:				
Rough or uncut, duty-free	(1)	1,708	(1)	2,514
Cut but not set, dutiable	(1)	5,183	(1)	7,657
Imitation, except opaque, dutiable:				
Not cut or faceted	(1)	28	(1)	(2)
Cut or faceted:				
Synthetic number	r 1,054,236	398	1,218,326	623
Other	(1)	4,487	(1)	5,825
Imitation, opaque, including imitation pearls, dutiable	(1)	154	(1)	337
Marcasites: Real and imitation, dutiable	(1)	(3)		
Total	(1)	255,792	(1)	298,386

r Revised.

[1] Quantity not recorded.

[2] No longer separately classified.

[3] Less than ½ unit.

Source: Bureau of the Census.

Precious and semiprecious gem stone exports were valued at $46.8 million compared with $40.5 million in 1963. Diamonds, both rough and uncut, accounted for almost 89 percent of total exports.

Reexports of all varieties of gem stone were valued at $64.3 million compared with $46.7 million in 1963. Diamond in the rough but uncut category accounted for 85 percent of total reexports.

TABLE 2.—U.S. imports for consumption of diamond (exclusive of industrial diamond), by countries

Country	1963				1964			
	Rough or uncut		Cut but unset		Rough or uncut		Cut but unset	
	Carats	Value (thousands)	Carats	Value (thousands)	Carats	Value (thousands)	Carats	Value (thousands)
Austria	---	---	---	---	---	---	584	$35
Belgium-Luxembourg	33,537	$3,282	522,383	$50,555	77,728	$9,264	583,207	60,155
Brazil	1,911	191	---	---	1,329	196	5	3
British Guiana	1,011	43	84	6	10,156	383	---	---
Canada	9,110	918	847	66	7,753	1,200	227	28
Central African Republic	---	---	---	---	102,919	5,451	---	---
Columbia	124	6	---	---	---	---	---	---
Congo (Léopoldville)	8,811	368	---	---	236	71	---	---
France	7,169	633	16,746	1,775	6,066	435	15,781	1,678
Germany, West	7	(1)	46,015	3,502	---	---	18,040	1,335
Ghana	1,993	49	---	---	858	53	---	---
Guinea	---	---	---	---	2,774	418	---	---
Hong Kong	---	---	227	50	---	---	329	41
India	---	---	207	16	---	---	535	111
Ireland	---	---	---	---	3,616	464	---	---
Israel	69,671	3,404	374,199	29,719	49,011	3,800	426,052	36,800
Italy	---	---	152	103	---	---	84	17
Japan	283	5	4,381	321	---	---	1,541	95
Liberia	19,051	1,395	---	---	8,417	806	---	---
Malta and Gozo	519	14	660	56	---	---	205	16
Netherlands	26,539	1,583	19,299	2,124	39,265	4,179	14,358	1,896
Nigeria	4,329	135	---	---	---	---	---	---
Sierra Leone	320,845	8,725	---	---	72,153	2,867	---	---
Republic of South Africa	112,448	11,558	27,089	4,736	138,015	12,162	23,721	4,918
Switzerland	37,402	1,549	501	205	33,748	2,192	783	364
U.S.S.R.	---	---	411	23	---	---	5,590	503
United Kingdom	906,340	86,977	4,280	699	894,260	100,928	5,387	754
Venezuela	55,905	1,971	---	---	78,486	2,960	---	---
Western Africa, n.e.c.[2]	71,096	4,148	---	---	20,995	1,868	---	---
Western Equatorial Africa	61,537	2,916	---	---	---	---	---	---
Total [3]	1,749,641	129,870	1,017,620	93,977	1,547,955	149,729	1,096,795	108,805

[1] Less than ½ unit.

[2] Not elsewhere classified.

Includes imports valued at less than $25,000 for following countries: Barbados, 1964; Jamaica, 1964; Mexico, 1963; Netherlands Antilles, 1964; Trinidad and Tobago, 1964; Gibraltar, 1963; Portugal, 1963-64; South Korea, 1964; Lebanon, 1963; Thailand, 1963; Senegal, 1964; Australia, 1964; New Zealand, 1964.

Source: Bureau of the Census.

WORLD REVIEW

Brazil.—Mineração Tejucana S.A. has been given the right to develop previously uneconomic alluvial diamond deposits along the Jequitinhonha River in the area of Diamantina and Bocaiuba, Minas Gerais. Economic exploitation is expected by dredging with equipment that can treat 3 million cubic meters per year for the recovery of about 30,000 carats, valued at about $600,000.[4]

A large crystal of gem beryl weighing about 15 pounds was found near Padre Paraiso, Municipality of Caraí, Minas Gerais and was valued at $143,000.[5]

Cameroon.—The Ivory Coast Diamond Corp. has been awarded diamond prospecting rights by the Ministry of Transportation, Mines, and Post and Communication.[6]

TABLE 3.—World production of gem diamond by countries

(Thousand carats)

Country	1963	1964
Africa:		
Angola	759	804
Central African Republic	121	221
Congo, (Brazzaville) Republic of [1] [e] [2]	341	316
Congo, (Léopoldville) Republic of the	296	295
Ghana	536	267
Guinea [1] [e]	22	22
Ivory Coast	63	120
Liberia [1]	240	298
Sierra Leone	555	516
Republic of South Africa:		
Pipe mines:		
Premier	522	556
DeBeers group [3]	921	928
Others	[r] 15	18
Alluvial	[r] 338	288
South-West Africa	1,076	1,373
Tanzania	276	12
Other Countries:		
Brazil [e]	175	175
British Guiana	60	60
India	1	2
U.S.S.R. [e]	240	240
Venezuela	38	58
World total	[r] 6,594	6,570

[e] Estimated. [r] Revised.
[1] Exports.
[2] Probable origin, Republic of the Congo.
[3] Includes some alluvial from DeBeers properties.

Canada.—Rock blasted from a quarry on Ile Ronde, Montreal, showed a similarity to South African kimberlite. This indicated a possibility that diamonds are embedded in the rock far below the surface.

Ceylon.—The Government formed the State Gem Mining Corporation to control internal and external trade in precious stones within the country. The corporation was expected to eliminate smuggling, thereby improving the Government's revenue and foreign exchange position in addition to insuring a reasonable return to the miner. The corporation shall have the authority to set license fees on all gem pits and impose taxes on all sections of the industry. The industry reforms caused a large number of gem dealers in Ratnapura to close their businesses.[7]

Chile.—Compañía Minera Caren continued to operate the only active lapis lazuli mine near the Argentine border in Coquimbo Province.

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[4] Mining Journal (London). V. 263, No. 6729, Aug. 7, 1964, p. 93.
[5] Bureau of Mines. Mineral Trade Notes. V. 59, No. 5, November 1964, pp. 4–5.
[6] Bureau of Mines. Mineral Trade Notes. V. 59, No. 4, October 1964, p. 17.
[7] Mining Journal (London). V. 263, No. 6731, Aug. 21, 1964, p. 137.

About 8,800 pounds, valued at $12,000, was produced during 1963. The bulk of this material was exported to Italy, France, United States, Germany, and Switzerland. Greater production was planned during 1964 to meet the increasing market created by hobbyists who are cutting and polishing lapis lazuli.[8]

Colombia.—During 1963 the Muzo, Coscuez, and Chivor emerald mines produced 50,560 carats of gem quality emerald. In addition, these mines produced 140,556 carats of low-grade emerald (morralla.)[9]

Czechoslovakia.—A northern area of the country where gem quality pyrope was formerly found has shown a similarity to the Siberian kimberlites. Studies of the pyrope rock have been made and it was concluded that further exploration for diamond was warranted.[10]

India.—The National Mineral Development Corporation of India undertook development of two new diamond mines at Majgawar and Ramkhiria. The yield of these mines was estimated at 30,000 and 12,500 carats per year respectively.[11]

Ivory Coast.—Three companies, Société Anonyme de Recherches et d'Exploitations Minière en Côte d'Ivoire, Société Diamantifere de Côte d'Ivoire, and Société Minière de Bandama produced diamonds during 1963. The Société Waston and the Diamond Corporation of the Ivory Coast prospected but did not begin operation in 1963. Government enforcement of its ban on clandestine operations eliminated the production of native prospectors.[12]

Sierra Leone.—The Government and Templesman and Bros., an American firm, have signed an agreement to set up a factory to cut and polish rough and uncut diamonds within the country. Operation of the facility is anticipated by the end of 1965.[13] A detailed article describing licensed diamond mining in the country was published.[14]

South Africa, Republic of.—Mining began at the Finsch Mine, the first new diamond mine in 50 years, in December. The mine, at Potmasburg on a claim discovered by A. T. Fincham was purchased by DeBeers Consolidated Mines for over $6 million in 1963. The area was being stripped of overburden to reach the diamond-bearing "blue ground." Treatment of the "yellow ground" in the overburden for the recovery of diamond has begun. Pilot plant experience will determine the design of the treatment and recovery plant to be built. The area will be mined by open pit methods to a depth of 300 feet. Operating results will then determine whether to continue open pit methods or begin underground mining.[15]

A special court in Pretoria opened hearings on the General Electric Co.'s application to patent the process for manufacturing diamond. The Transvaal and Orange Free State Chamber of Mines opposed the application by claiming that the synthesis of diamond is an obvious process and not an invention. The legal dispute was expected to be lengthy because of the affidavits entered by affected parties and the legal efforts by the Chamber of Mines to require deponents to give evidence in person.[16]

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[8] Bureau of Mines. Mineral Trade Notes. V. 59, No. 2, August 1964, p. 34.

[9] Bureau of Mines. Mineral Trade Notes. V. 60, No. 1, January 1965, pp. 12–13.

[10] Mine and Quarry Engineering (London). Czech Diamond Prospects. V. 30, No. 2, February 1964, p. 96.

[11] Mining Journal (London). V. 262, No. 6709, Mar. 20, 1964, p. 216.

[12] Bureau of Mines. Mineral Trade Notes. V. 59, No. 1, July 1964, p. 13.

[13] Mining Journal (London). Sierra Leone Diamond Factory. V. 264, No. 6752, Jan. 15, 1965, pp. 43, 45.

[14] Fairbairn, W. C. Licensed Diamond Mining in Sierra Leone. Min. Mag. (London), v. 112, No. 3, March 1965, pp. 166–167, 169, 171, 173, 175, 177.

[15] Mines Magazine. New Diamond Mine. V. 55, No. 3, March 1965, pp. 23–24.

South-West Africa.—Diamond dredging activities continued in the offshore marine sediments. Offshore prospecting was underway by several mining companies. Notable among these was the *Rockeater*, a ship specifically designed for underwater mineral sampling, whose sampling operations were supported by the DeBeers Consolidated Mines, Ltd.

Marine Diamond Corp., Ltd., continued to recover diamonds from its offshore concession. During the period of January 1 to May 31, 1964, the company mined almost 102,000 carats of diamonds.

Mining activities continued along the territory's coastal belt. Consolidated Diamond Mines' Vacu-Veyor, essentially a large vacuum cleaner, proved successful for removing sand and gravel from bed rock.[17] An article provided a description of Consolidated Diamond Mines diamond mining practices.[18]

South-West Africa continued to produce and export semiprecious gem materials such as agate, amazonite, quartz (amethyst, green and rose), chalcedony, jasper, and tourmaline.

Thailand.—During 1963 about 13 million carats of precious and semiprecious materials was imported and over 11 million carats was exported. The bulk of the material imported consisted of synthetic or reconstructed precious or semiprecious stones.[19]

Upper Volta.—Diamond exploration rights were awarded to the West African Selection Trust, Ltd., for 1 year commencing at the beginning of 1964 and to be renewable for 2 years. The organization agreed to spend $62,000 per year for exploration. Geological surveys had been completed for only 20 percent of the territory involved, and traces of diamond were found near the Ghanaian border.[20]

U.S.S.R.—Both industrial and gem diamonds were mined at Mirny in Yakutia, Eastern Siberia, by opencast methods. A new concentrating plant capable of operating the entire year was being built. Finds of new kimberlite pipes were reported north of Mirny on the Olenck River.[21]

Zambia.—Rio Tinto, Ltd., discontinued exports of higher grade emerald from the Sandawana mine near Belingwe in order to form a domestic cutting industry that will export cut emerald. Rio Tinto planned to continue to export lower grade uncut emerald.[22]

TECHNOLOGY

Detection by loupe or Gemolite that a diamond was coated to enhance its color was reported. The coating, a foreign substance, is applied to the surface of certain diamonds to raise their color by neutralizing their true yellow color. Recent application of the phase microscope has brought the nature of coated surfaces of diamond into critical focus and photographic records were made under 500 to 1,000 magnification. The pictures reveal clearly where coatings were applied. They confirm earlier findings of characteristic markings that were seen with use of 10X loupe or a Gemolite.[23]

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[16] Bureau of Mines. Mineral Trade Notes. V. 58, No. 5, May 1964, p. 18.

[17] South African Mining & Engineering Journal (Johannesburg). Mining Activities in S.W.A. V. 75, Pt. 2, No. 3725, June 26, 1964, pp. 187–188, 191.

[18] South African Mining & Engineering Journal (Johannesburg). 26-million to 1 Concentration Operation at Cons. Diamonds. V. 76, Pt. 1, No. 3759, Feb. 19, 1965, pp. 410–416.

[19] Bureau of Mines. Mineral Trade Notes. V. 59, No. 6, December 1964, pp. 18–19.

[20] Bureau of Mines. Mineral Trade Notes. V. 58, No. 5, May 1964, p. 23.

[21] Mining & Minerals Engineering (London). Diamond Mining in Yakutia. V. 1, No. 7, March 1965, p. 277.

[22] Bureau of Mines. Mineral Trade Notes. V. 60, No. 3, March 1965, p. 7.

The development of an ultramodern automatic diamond sorting machine was reported. The machine was based on techniques in various scientific fields that electronics coordinated effectively, as X-rays, precision mechanics, vacuum, and compressed air.[24]

Steps taken to improve gem diamond production at the operations of the leading gem diamond producer was briefly described. The installation of two Wedag medium scoop wheel separators by Consolidated Diamond Mines of South-West Africa Ltd., should contribute considerably in increasing production.[25]

Advanced equipment used in diamond prospecting on the sea-floor sampling program conducted on behalf of the DeBeers group off the coast of South-West Africa was described.[26]

Method and equipment used in the production of diamonds in the U.S.S.R. were described.[27]

Tests for identifying artificial and improved turquoise were reported. Many substitutes are offered in place of genuine turquoise. The offerings are of three types: Compacted poor quality turquoise, colored and soaked with plastic; other natural substances similarly treated; and wholly artificial aggregates.[28]

An article was written on the misleading use of names on maps indicating turquoise locations in the Turquoise Mountains east of Baker, Calif.[29]

The use of synthetic sapphire jewel bearings in gas flow meters was discussed. Synthetic sapphires are nonmagnetic, corrosion-resistant, easily obtainable, and have miniature dimensions within critical tolerances.[30]

The occurrence of needle-like structures and some color phases in quartz are described.[31]

A guide on gems, minerals, crystals, and ores was written for professional mineralogists, gem cutters, collectors, and hobbyists. The book describes where to find them, methods of identification, cutting, and displaying.[32]

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[23] Miles, Eunice R. First Close-Up Shots of Coated Diamonds. Jewelers' Circular-Keystone, v. 75, No. 1, October 1964, pp. 70–73, 104–108.

[24] Mining Journal (London). Automatic Rough Diamond Sorter. V. 263, No. 6743, November 1964, p. 355. Mining Magazine (London). Automatic Rough Sorter. V. III, No. 6, December 1964, p. 391.

[25] Mining Magazine (London). Dense Medium Separators for Diamonds. V. III, No. 6, December 1964, pp. 381–383.

[26] Mining Magazine (London). Sea-Floor Sampling. V. III, No. 6, December 1964, pp. 403, 405. South African Mining & Engineering Journal (Johannesburg). Prospecting For Diamonds Off South-West Africa. V. 75, Pt. 2, No. 3743, October 1964, pp. 1208–1209.

[27] World Mining. How Russia Mines More Diamonds. V. 17, No. 13, December 1964, p. 34.

[28] Pough, F. H. Turquoise and Its Substitutes. Jewelers' Circular-Keystone, v. 84, No. 4, January 1964, pp. 78, 80 and 81.

[29] Pemberton, H. E. Place Names in the Turquoise Mountains. The Mineralogist, v. 32, No. 5, October 1964, pp. 10–13.

[30] Chemical Engineering. Synthetic Jewel Bearings Make Accurate Gas Flow Meter. V. 71, No. 22, October 1964, p. 146.

[31] Pough, F. H. Quartz Jewelry Stones. Jewelers' Circular-Keystone, v. 75, No. 1, October 1964, pp. 86–90, 98–100.

The cultivation of high-quality pearls in fresh-water mussels was described. The fresh-water mussel often is larger and has a thicker shell than the Japanese salt-water oyster. Fresh-water mussels yield two crops of non-nucleated pearls.[33]

The surface structures of crystal faces of natural and synthetic emeralds were reported. By using a reflection and phase contrast microscope, a clear distinction can be made between natural and synthetic emeralds.[34]

The geologic occurrence, variations, color zoning, and inclusions were discussed in an article on tourmaline.[35]

Goldmanite, a new garnet, has been identified as a constituent of a metamorphosed uranium-vanadium deposit in the Sandy (or South Laguna) mine area, about 4 miles southeast of Laguna, N. Mex. Occurrence, separation, properties, composition, and analytical procedures are described.[36]

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[32] Pearl, R. M. Gems, Minerals, Crystals and Ores. The Odyssey Press, New York, 1964, pp. 320.

[33] Pough, F. H. Cultured Pearls—Shape and Luster Distinguish Fresh-Water Cultured Pearls. Jewelers' Circular-Keystone, v. 84, No. 11, July 1964, pp. 72–76, 92.

[34] Sunagawa, I. A Distinction Between Natural and Synthetic Emeralds. The American Mineralogist, v. 49, Nos. 5 and 6, May–June 1964, pp. 785–792.

[35] Ransom, J. E. Tourmaline—The Geological Saga of a Crystal. The Mineralogist, v. 32, No. 4, August 1964, pp. 2–9.

[36] Moench, R. H. and R. Meyrowitz. Goldmanite, a Vanadium Garnet from Laguna, New Mexico. The American Mineralogist, v. 49, Nos. 5 and 6, May–June 1964, pp. 644–655.

Gold

By J. Patrick Ryan[1]

◆

MINE PRODUCTION of recoverable gold in the United States rose slightly after declining for 3 consecutive years. World gold production increased for the 11th consecutive year, again establishing an alltime record.

In the United States the increased output of gold ore, chiefly from the Homestake mine, largely offset the falloff in production from placer mining; gold recovered as a byproduct of base metal ores increased. The gain in world output again was attributed almost entirely to the increased production from South African mines which contributed about 63 percent of the estimated world gold production.

Consumption of gold in domestic arts and industries increased 65 percent reaching an alltime record, more than 3 times domestic mine production. The deficit was supplied from the Treasury stock.

The outflow of gold from U.S. stocks dropped to about one-third of that in 1963, reflecting a reduction in the balance-of-payments deficit and conversion of U.S. dollars to gold. The U.S. gold stock at yearend was $15,471 million, the lowest level since March 1939. Free world gold reserves totaled $43,035 million at yearend, a gain of $725 million for the year.

The London market price of gold fluctuated in a narrow range near the official price of $35 per ounce. Sales of gold by the U.S.S.R. totaled about $500 million, about half of which was sold in the London market.

LEGISLATION AND GOVERNMENT PROGRAMS

A bill (H.R. 9756) to revitalize the American gold-mining industry was introduced in the 88th Congress, 2d Session, in January and referred to the Committee on Interior and Insular Affairs without further action. This bill was practically identical to S. 2125 on which hearings were held by the Subcommittee on Minerals, Materials, and Fuels in October 1963. Essentially, the bill proposed to compensate eligible primary gold producers for the difference between production costs in the fourth quarter of 1939 and current costs.

Ten contracts aggregating $681,123 were executed during the year for gold and gold-silver exploration under the Government program of financial assistance, administered by the Office of Minerals Exploration. The Government share of the exploration cost was 50 percent or $340,561. The following exploration projects were active or in force in 1964:

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[1] Commodity specialist, Division of Minerals.

Operator:	*Location*	*Total cost*
Ivers Mining Co., Inc	Esmeralda County, Nev	$46, 773
Austin H. Merrill	Shasta County, Calif	41, 860
Brainerd, S. E., and N. M	Sierra County, Calif	15, 080
Larrigon Mining Co	Ravalli County, Mont	31, 610
Pyramid Mines, Inc	Mariposa County, Calif	42, 200
Mugwump Mining Co	Sierra County, Calif	70, 440
W. S. Moore Co	Rio Grande County, Colo	81, 680
Ruby Silver Mines, Inc	Jefferson County, Mont	132, 800
Grand Deposit Mining Co	Beaverhead County, Mont	71, 880
Original Sixteen to One Mine, Inc.	Sierra County, Calif	43, 300
Clyde D. Painter	Idaho County, Idaho	41, 830
Vitro Minerals Corp	Fergus County, Mont	93, 740
Consolidated Allegheny Mines, Inc.	Sierra County, Calif	101, 220
Consolidated Eureka Mining Co.	Eureka County, Nev	118, 600
Old English Gold Corp	Nye County, Nev	34, 900
Richard W. Rowe	Fourth Judicial Dist., Alaska	12, 300
Keystone Mines, Inc	Fairbanks Dist., Alaska	79, 900
Dickey Exploration Co	Sierra County, Calif	50, 320
Best Mines, Inc	do	80, 090
Frank O. Richardson	San Juan County, Colo	57, 300
Total		1, 247, 823

DOMESTIC PRODUCTION

Increased gold output in South Dakota, Arizona, Montana, and Utah offset losses resulting from the continuing decline of placer mining operations in Alaska and California and lower output from lode mining in Nevada and Washington. The gold-mining industry continued to be adversely affected by rising costs in relation to the fixed price of gold. Increased efficiency and improved technology offset rising costs to some extent, thereby maintaining production and reserves at a few mines, but depletion of minable reserves forced some placer mines to close.

The continuing sharp drop in Alaska's gold production again reflected the curtailment of placer mining by the United States Smelting, Refining & Mining Co. which closed its major dredging operations in the Fairbanks district. The company operated three dredges during 1964, one at Hogatza, one at Chicken Creek, and one at Fairbanks (part time).[2]

The Homestake mine at Lead, S. Dak., the leading gold producer, recorded new highs in the quantity of ore milled and bullion produced. Value of recovered bullion increased 7 percent to $21.7 million. Ore milled increased to 2.03 million tons with an average recovered grade of $10.68 per ton, compared with 1.91 million tons yielding $10.62 in 1963. Metallurgical recovery was 96.2 percent. Measured ore reserves at yearend totaled 16.8 million tons with an estimated average grade of 0.315 ounces ($11.01) of gold per ton, an increase of 1.6 million tons, but a decrease of 31 cents in grade.[3] About 1,900 persons were employed at the mine.

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[2] United States Smelting, Refining & Mining Co. Annual Report 1964.

Carlin Gold Mining Co., a subsidiary of Newmont Mining Corp., began construction of a 2,000-ton-per-day all-slime cyanide plant at its Carlin mine near Elka, Nev. The estimated ore reserve was 7 million tons. About 2 million tons of overburden was stripped in preparation for open-pit mining. Overall cost of the project was estimated at $7 million.

Approximately 2,700 persons were employed in the gold-mining industry at 355 lode and placer mining operations.

Output of gold in California chiefly from placer mines, again dropped sharply. Most of the 10-percent increase in the Arizona production reflected increased output of copper ore yielding byproduct gold. Similarly, a 57-percent gain in Montana production was largely due to the sharp rise in copper output from which gold was recovered as a byproduct.

South Dakota and Utah, the two leading gold-producing States, furnished 62 percent of the total domestic gold output. The Homestake mine in South Dakota contributed 42 percent of the U.S. gold output. Most of the gold output from Utah was recovered as a byproduct of copper ore from the Utah Copper mine.

The 25 leading U.S. gold producers contributing 90 percent of the total domestic output included 5 lode mines, 6 placer mines, 9 copper mines, 2 copper-lead-zinc mines, and 3 lead-zinc mines.

TABLE 1.—Salient gold statistics

	1955–59 (average)	1960	1961	1962	1963	1964
United States:						
Mine production .... thousand troy ounces..	1,769	1,667	1,548	1,543	1,454	1,456
Value .... thousands..	$61,902	$58,337	$54,189	$53,990	$50,889	$50,971
Ore (dry and siliceous) produced:						
Gold ore .... thousand short tons..	2,310	2,267	2,060	2,159	2,459	2,631
Gold-silver ore .... do....	145	347	248	353	223	224
Silver ore .... do....	641	641	565	524	556	542
Percentage derived from—						
Dry and siliceous ores	45	47	48	47	51	54
Base-metal ores	35	37	39	36	36	37
Placers	21	16	13	17	13	9
Refinery production ..... thousand troy ounces..	1,787	1,680	1,567	1,556	1,469	1,469
Imports, general [1] .... do....	6,193	9,322	1,615	4,312	1,281	1,169
Exports [1] .... do....	1,328	47	22,146	10,884	5,820	12,078
Stocks Dec. 31: Monetary [2] .... millions..	$21,317	$17,804	$16,947	$16,057	$15,596	$15,471
Consumption in industry and the arts thousand troy ounces..	1,701	3,000	2,775	3,576	2,920	4,801
Price: Average per troy ounce [3]	$35.00	$35.00	$35.00	$35.00	$35.00	$35.00
World: Production .... thousand troy ounces..	33,000	38,200	39,700	42,300	44,200	46,100

[1] Excludes coinage.
[2] Includes gold in Exchange Stabilization Fund.
[3] Price under authority of Gold Reserve Act of Jan. 31, 1934.

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[3] Homestake Mining Co. 87th Annual Report. Dec. 31, 1964, pp. 5, 22.

TABLE 2.—Mine production of gold in the United States in 1964, by months

Month	Troy ounces	Month	Troy ounces
January	116,385	August	107,921
February	116,097	September	118,914
March	121,328	October	140,709
April	121,050	November	123,294
May	133,831	December	121,921
June	134,680		
July	100,178	Total	1,456,308

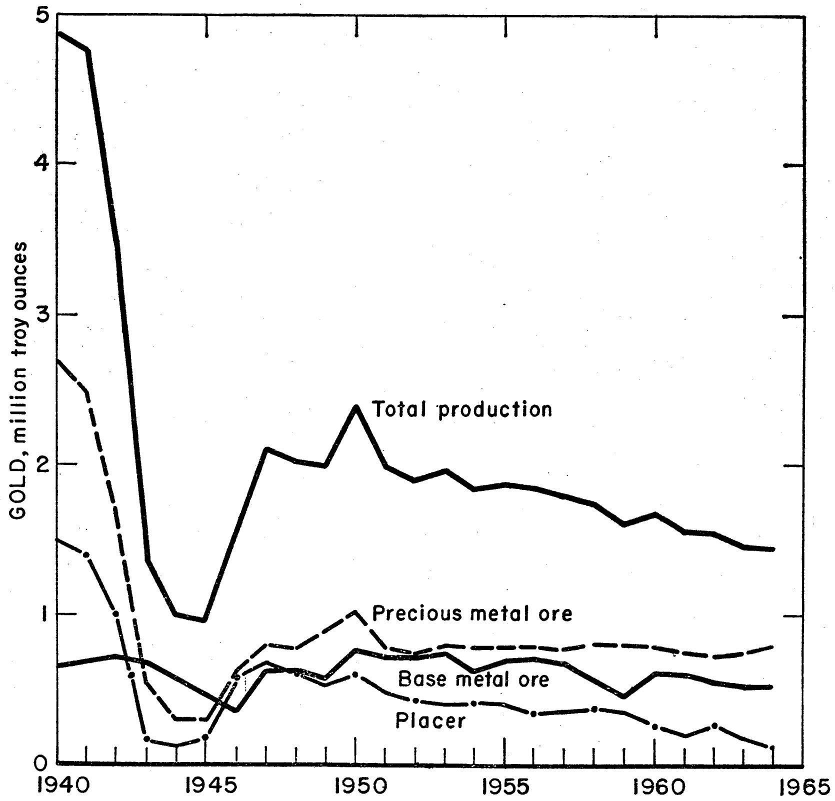

FIGURE 1.—Gold production in the United States.

TABLE 3.—Twenty-five leading gold-producing mines in the United States in 1964, in order of output

Rank	Mine	District or region	State	Operator	Source of gold
1	Homestake	Whitewood (Ida Gray).	South Dakota	Homestake Mining Co.	Gold and gold-silver ores.
2	Utah Copper	West Mountain	Utah	Kennecott Copper Corp.	Copper and gold-silver ores.
3	Knob Hill and Gold Dollar.	Republic	Washington	Knob Hill Mines, Inc.	Gold ore.
4	Yuba Unit	Yuba River	California	Yuba Consolidated Gold Fields.	Dredge.
5	Copper Queen-Lavender Pit.	Warren	Arizona	Phelps Dodge Corp.	Copper ore.
6	New Cornelia	Ajo	do	do	Copper and gold-silver ores.
7	Mayflower Unit	Blue Ledge	Utah	Hecla Mining Co	Lead-zinc ore.
8	Idarado	Red Mountain-Upper San Miguel.	Colorado	Idarado Mining Co.	Copper and lead-zinc ores.
9	San Manuel	Old Hat	Arizona	Magma Copper Co	Copper ore.
10	Gold King	Wenatchee River	Washington	L-D Mines	Gold ore.
11	Iron King	Big Bug	Arizona	Shattuck Denn Mining Corp.	Lead-zinc ore.
12	Hogatza River	Hughes	Alaska	United States Smelting, Refining, and Mining Co.	Dredge.
13	Berkeley Pit	Summit Valley	Montana	The Anaconda Company.	Copper ore.
14	Morenci	Copper Mountain.	Arizona	Phelps Dodge Corp.	Copper and gold-silver ores.
15	Magma	Pioneer	do	Magma Copper Co	Do.
16	Chicken Creek	Fortymile	Alaska	United States Smelting, Refining, and Mining Co.	Dredge.
17	United States and Lark.	West Mountain (Bingham).	Utah	do	Lead and lead-zinc ores.
18	Fairbanks Unit	Fairbanks	Alaska	do	Dredge.
19	Gold Bug	Little Rockies	Montana	Northern Continental, Inc.	Gold-silver ore.
20	Original Sixteen to One.	Alleghany	California	Original Sixteen to One Mine, Inc.	Gold ore.
21	Eagle	Red Cliff (Battle Mountain).	Colorado	The New Jersey Zinc Co.	Copper and zinc ores.
22	Chino	Central	New Mexico	Kennecott Copper Corp.	Copper ore.
23	Nyac	Aniak	Alaska	New York-Alaska Gold Dredging Corp.	Dredge.
24	Prince Creek	Iditarod	do	Prince Creek Mining Co.	Do.
25	Butte Hill Copper Mines.	Summit Valley	Montana	The Anaconda Company.	Copper ore.

TABLE 4.—Production of gold in 1962–64 in the United States, and by source 1964

(Troy ounces)

State	1962	1963	1964 by type of mine production						Refinery production[1]
			Placers	Dry ore	Copper ore	Lead and zinc ores	Complex base metal ores	Total	
Alaska	165,259	99,573	56,284	2,132	--------	--------	--------	58,416	58,500
Arizona	137,207	140,030	10	973	134,020	31	18,642	153,676	157,000
California	106,272	86,867	65,938	4,887	1	13	49	[2] 71,028	71,770
Colorado	48,882	33,605	1,050	3,088	2,835	933	34,216	42,122	41,600
Idaho	5,845	5,477	104	2,174	1,220	1,714	465	5,677	5,500
Montana	24,387	18,520	292	7,648	18,517	2,631	27	[4] 29,115	27,850
Nevada	62,863	98,879	1,222	63,633	25,379	235	--------	90,469	92,500
New Mexico	7,529	7,805	1	569	5,251	207	82	6,110	7,000
North Carolina	460	33	--------	--------	--------	--------	--------	--------	2
Oregon	822	1,809	322	311	28	--------	--------	661	1,000
Pennsylvania	(5)	(5)	(5)	(5)	(5)	(5)	(5)	(5)	--------
South Dakota	577,232	576,726	3	616,910	--------	--------	--------	616,913	619,650
Tennessee	158	137	--------	--------	--------	--------	133	133	122
Utah	311,924	285,907	--------	917	243,277	259	43,221	287,674	290,000
Washington	93,671	98,638	--------	92,665	--------	3	--------	[6] 94,308	96,500
Wyoming	--------	4	6	--------	--------	--------	--------	6	6
Total	1,542,511	1,454,010	125,232	795,907	430,528	6,026	96,835	1,456,308	1,469,000
Percent[7]	--------	--------	9	54	30	(3)	7	100	--------

[1] U.S. Bureau of the Mint.
[2] Includes gold recovered from tungsten ore.
[3] Less than 0.5 percent.
[4] Includes gold from manganese ore.
[5] Included with Washington.
[6] Includes gold recovered from magnetite-pyrite in Pennsylvania.
[7] Percentage based on total, excluding 1,780 ounces obtained from other ores.

TABLE 5.—Ore, old tailings, etc., yielding gold produced in the United States, and average recoverable content, in troy ounces of gold per ton in 1964

State	Gold ore		Gold-silver ore		Silver ore		Copper ore		Lead ore		Zinc ore		Zinc-lead, zinc-copper, and zinc-lead-copper ores		Total ore	
	Short tons	Average ounces of gold per ton	Short tons	Average ounces of gold per ton	Short tons	Average ounces of gold per ton	Short tons	Average ounces of gold per ton	Short tons	Average ounces of gold per ton	Short tons	Average ounces of gold per ton	Short tons	Average ounces of gold per ton	Short tons	Average ounces of gold per ton
Alaska	2,493	0.855	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	2,493	0.855
Arizona	243	.708	141,246	0.006	481	0.017	82,505,327	0.002	3,093	0.009	15,000	----------	428,484	0.044	83,093,874	.002
California	9,753	.465	----------	----------	535	.664	19	.053	1,949	.007	----------	----------	3,600	.014	15,856	[1].321
Colorado	9,154	.238	262	3.210	9,722	.007	34,490	.082	1,313	.041	294,267	0.003	699,390	.049	1,048,598	.039
Idaho	1,338	.857	3	1.333	368,240	.003	71,547	.017	183,597	.009	64,657	----------	858,029	.001	1,547,411	.004
Montana	914	.449	22,188	.287	55,920	.016	13,613,452	.001	4,740	.030	1,080,743	.002	215	.126	14,778,172	.002
Nevada	394,364	.161	60	1.650	20,050	.002	8,390,107	.003	3,080	.076	244	.008	----------	----------	8,807,905	.010
New Mexico	35	.714	15,478	.035	434	.009	7,212,912	.001	119	.034	308,857	.001	14,811	.006	7,552,646	.001
South Dakota	2,032,955	.303	18	21.389	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	2,032,973	.303
Utah	----------	----------	44,392	.008	85,257	.007	24,580,381	.010	6,576	.038	43,600	----------	515,245	.084	25,275,451	.011
Undistributed[2]	179,670	.516	600	.172	1,134	.093	57	.491	----------	----------	186,691	----------	1,447,120	----------	[3] 3,424,578	.028
Total	2,630,919	.298	224,247	.042	541,773	.006	136,408,292	.003	204,467	.012	1,994,059	.002	3,966,894	.024	147,579,957	.009

[1] Includes byproduct gold from tungsten ore.
[2] Includes Oregon, Pennsylvania, Tennessee, and Washington.
[3] Includes magnetite-pyrite ore from Pennsylvania.

TABLE 6.—Gold produced in the United States from ore and old tailings in 1964, by States and methods of recovery, in terms of recoverable metal

State	Total ore, old tailings, etc., treated (thousand short tons) [1]	Ore and old tailings to mills					Crude ore to smelters	
		Thousand short tons [1]	Recoverable in bullion		Concentrates smelted and recoverable metal			
			Amalgamation (troy ounces)	Cyanidation (troy ounces)	Concentrates (short tons)	Troy ounces	Thousand short tons	Troy ounces
Alaska	2	2	2,035				(2)	347
Arizona	86,808	86,154	6		2,666,493	138,669	653	14,991
California	16	10	4,372		3,478	317	6	401
Colorado	1,052	1,028	9,433		156,670	27,650	24	3,989
Idaho	1,649	1,594	561		220,475	4,742	55	270
Montana	14,872	14,718	4		420,454	21,142	154	7,677
Nevada	13,382	13,326	569	62,674	281,273	24,828	56	1,176
New Mexico	7,915	7,811			329,859	5,533	105	576
South Dakota	2,033	2,033	436,687	179,838			(2)	385
Utah	25,308	25,095			776,739	286,419	213	1,255
Undistributed [3]	3,173	3,167	69	12,259	144,397	80,731	6	1,721
Total	156,210	154,938	453,736	254,771	4,999,838	590,031	1,272	32,788

[1] Includes some non-gold-bearing ores not separable.
[2] Less than 500 short tons.
[3] Includes Oregon, Pennsylvania, Tennessee, and Washington.

TABLE 7.—Gold produced at amalgamation and cyanidation mills in the United States and percentage of gold recoverable from all sources

Year	Bullion and precipitates recoverable (troy ounces)		Gold from all sources (percent)			
	Amalgamation	Cyanidation	Amalgamation	Cyanidation	Smelting [1]	Placers
1955–59 (average)	445,289	255,567	25.2	14.4	39.7	20.7
1960	438,207	210,354	26.3	12.6	45.2	15.9
1961	434,134	186,086	28.0	12.0	46.9	13.1
1962	455,412	173,386	29.5	11.2	42.1	17.2
1963	437,264	218,212	30.1	15.0	42.2	12.7
1964	453,736	254,771	31.2	17.5	42.7	8.6

[1] Crude ores and concentrates.

TABLE 8.—Gold production at placer mines in the United States, by methods of recovery

Method and year	Mines producing	Washing plants	Material treated (thousand cubic yards)	Gold recoverable		
				Thousand troy ounces	Value (thousands)	Average value per cubic yard
Bucketline dredging:						
1955–59 (average)	19	29	45,697	296	$10,340	$0.226
1960	17	24	33,464	228	7,986	.239
1961	19	24	33,806	177	6,192	.183
1962	20	22	25,590	242	8,456	.330
1963	17	22	18,431	161	5,651	.307
1964	13	13	14,382	103	3,604	.251
Dragline dredging:						
1955–59 (average)	14	10	384	2	72	.188
1960	20	20	144	1	47	.329
1961	16	16	[1] 608	1	43	.071
1962	13	13	532	1	47	.088
1963	11	11	266	2	70	.265
1964	19	13	195	2	68	.350
Hydraulicking:						
1955–59 (average)	40	8	160	2	76	.475
1960	33	33	282	3	93	.330
1961	19	19	104	3	107	1.029
1962	21	21	124	2	83	.669
1963	12	12	43	1	45	1.056
1964	11	11	30	(2)	10	.323
Nonfloating washing plants:						
1955–59 (average)	104	107	2,194	64	2,226	1.015
1960	80	80	938	30	1,045	1.114
1961	81	81	957	19	668	.698
1962	45	45	839	16	551	.657
1963	50	67	638	[1] 14	499	.782
1964	55	49	585	[1] 14	489	.836
Underground placer, small-scale hand methods, and suction dredge:						
1955–59 (average)	88	2	112	3	95	.848
1960	89	89	60	2	73	1.207
1961	103	103	141	2	73	.518
1962	74	74	314	4	128	.408
1963	133	82	139	6	194	1.403
1964	87	56	49	6	212	4.292
Total placers:						
1955–59 (average)	265	156	48,549	366	12,810	.264
1960	239	246	34,888	264	9,244	.265
1961	238	243	35,616	202	7,083	.199
1962	173	175	27,399	265	9,265	.338
1963	223	194	19,517	185	6,452	.331
1964	185	142	15,241	125	4,383	.287

[1] Does not include commercial sand and gravel operations recovering byproduct gold.
[2] Less than 500 ounces.

CONSUMPTION AND USES

Industry and Arts.—The net consumption of gold in domestic industries increased sharply to 4.8 million ounces, an alltime record.

Data compiled by the Office of Gold and Silver Operations, U.S. Treasury Department, indicate that about 76 percent of the total gold sold or transferred was for jewelry, artistic, and dental uses; the remainder was used chiefly for electrical and electronic components in defense and aerospace equipment and for other industrial products.

The Committee for Research on the Properties and Uses of Gold, Inc., continued its studies to develop new industrial applications for gold. The Committee reported that gold films on glass can reduce harmful ultraviolet radiation, yet by proper processing can retain almost full visible transmission properties. Investigators at the University of California showed that, by controlling film thickness and heat-treatment procedures, the transmission in the visible region can be maintained at high and almost constant values, whereas transmission in the infrared and ultraviolet regions can be decreased substantially.

Researchers at the University of Florida demonstrated that electroplated gold coatings protected high-strength alloy steels from deterioration of mechanical properties due to hydrogen embrittlement. It was found that where the substrate was in a condition to be embrittled, the gold plate always afforded substantial protection.

Mirror-bright gold finishes were used to protect delicate electronic instruments in ballastic missile and space programs, such as the gold coatings used by Bell Aerosystems Co. to protect digital velocity meters on the Agena space vehicles. All brackets, covers, and surfaces in contact with outerspace were gold coated to withstand the corrosive atmosphere and to reflect the intense heat away from the instruments.

An improved gold-solder combination was developed by Monsanto Research Corp. which overcomes the high reactiveness of ordinary solders with gold in printed circuit boards by slowing down the reaction. This may lead to increased use of gold in this application.

Gold coatings increased the efficiency of condensers used in distillation of seawater and may be used in compact air conditions, dehumidifiers, steam powerplants, and water recovery systems for spaceships, and industrial distillation. Research indicated that noble-metal surfaces promote condensation of water in drops indefinitely, without addition of drop-promoting chemicals to the system. Tests showed that condenser tube surfaces coated with a thin layer of gold or silver can increase heat-transfer coefficients by as much as 50 percent or more over uncoated tubes.

Studies of metallic film lubricants at the NASA Goddard Space Flight Center showed that in small high-speed motors, gold-plated bearings gave superior performance under extreme conditions if they are run in silver-plated raceways and silver-plated retainers.

Gold and other noble-metal contacts were used to an increasing extent in applications where these metals in electrodeposited form have unique properties, particularly suitable for contact service.

Gold leaf was used in surgery to patch punctured blood vessels and other defects in body tissues including the brain. Its adherence, malleability, chemical inertness, and tensile strength reportedly made gold leaf particularly suited for such use.

TABLE 9.—Gold consumption in industry and the arts, in the United States

(Troy ounces)

Year	Issued for industrial use	Returned from industrial use	Net industrial consumption
1955–59 (average)	2,434,148	733,138	1,701,010
1960	3,700,000	700,000	3,000,000
1961	3,912,554	1,137,554	2,775,000
1962	4,485,670	909,670	3,576,000
1963	4,252,478	1,332,478	2,920,000
1964	5,887,400	1,086,400	4,801,000

Source: U.S. Bureau of the Mint.

MONETARY STOCKS

The total U.S. gold stock declined $125 million during the year and stood at $15,471 million on December 31, the lowest level since March 1939. The 1964 gold outflow was less than one-third that in 1963 and was the smallest since 1955. Acquisitions by the United States from the London gold pool and purchases from Italy largely offset U.S. sales to France, West Germany, and other European countries.

The rate of conversion of U.S. dollars to gold declined as a result of a reduction in the balance-of-payments deficit on regular transactions from $3,261 million to $3,006 million. The ratio of gold reserves to Federal Reserve note and deposit liabilities was 27.5 percent at yearend, compared with 29.7 at the end of 1963; 25 percent was required for legal cover.

Gold reserves of free world central banks and governments and international banking institutions at yearend were estimated at $43,060 million, $725 million more than at the end of 1963. The addition to monetary reserves was about $175 million less than in 1963. Most of the newly acquired gold went into reserves of the leading Western European countries. Of a total estimated new gold supply of $1,800 million, about $1,000 million was absorbed in private uses and holdings. The U.S. reserve of $15,471 million thus constituted about 36 percent of the total free world gold reserves. Gold reserves of other principal free world countries, in million dollars, were as follows: West Germany, 4,300; France, 3,900; Switzerland, 2,700; United Kingdom, 2,100; Italy, 2,100; Netherlands, 1,700; Belgium, 1,500; and Canada, 1,000. The International Monetary Fund reported gold reserves of $2,200 million.[4]

In connection with the U.S. gold reserve, Secretary of the Treasury Dillon stated on June 29, before the Senate Finance Committee:

> . . . Paralleling this improvement (reduction in balance-of-payments deficit in fiscal year 1964) confidence has been restored in our ability to achieve a balance in our payments within a reasonable time. This in turn has staunched the drain on our gold stock. After declining by an average of 1.7 billion a year over the 1959–60 period, and by roughly half that rate during 1961 and 1962, our total gold stock today is virtually unchanged from ten months ago—by far the longest period of stability during the past six years . . .

U.S. net short-term liabilities to foreign interests (liabilities less claims) payable in dollars, increased $1,100 million to $18,500 million at yearend. These liabilities constitute a potential claim on the U.S. gold reserve. About two-thirds of the net liabilities was payable to Western European countries and Canada.

PRICES

Adequate supplies of gold were available to meet demand in the London market and prices were relatively stable. The range of prices in dollars was between a low of $35.05–$35.07 and a high of $35.12–$35.14. The sterling price fluctuations were appreciably greater, reflecting variations in the sterling-dollar exchange rate. London market supplies came chiefly from South Africa, augmented by sales by the U.S.S.R. which aggregated about 7.7 million ounces, valued at $269.4 million. A supply deficiency in the last one-third of the year was balanced by withdrawals from the International Gold Pool.

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[4] Federal Reserve Bulletin. V. 51, No. 3, March 1965, pp. 494–503.

In gold markets outside of London, prices of gold bars averaged $0.24 to $3.18 higher than the London quotation, except in the Bombay market where trading was in local currencies, not readily convertible, which reflected local political conditions and monetary habits. Average prices per ounce in U.S. dollars were as follows:

Market:	*Price*	Market—Continued	*Price*
Manila	$35.47	Beirut	$35.33
Hong Kong	38.27	Paris	35.33
Bombay	53.04	Buenos Aires	37.62

Gold sales by the U.S.S.R. in markets other than London were estimated to total $230 million, bringing the total sales by the U.S.S.R. in world markets to about $500 million, nearly as much as in 1963.

Demand for gold coins in the London market continued strong. Net export of gold coins from the United Kingdom, was valued at nearly $81 million. More than half of the gold coin exported went to Greece. The premium on the U.S. $20 goldpiece ranged from 21 to 24 percent; the premium was 17 to 18 percent on new sovereigns; 30 to 32 percent on napoleons; 39 to 42 percent on the Swiss 20-franc coin; and 71 to 73 percent on German 20-mark coins.

Appreciable speculation concerning a revaluation of gold was evident, especially in the latter part of the year when the British pound had to be supported by short-term credits from the International Monetary Fund, the Federal Reserve, and the Export-Import Bank. In connection with the U.S. official price of gold, Secretary of the Treasury Dillon stated before the National Industrial Conference Board on September 17:

> . . . Having returned only a few days ago from the annual meetings of the International Monetary Fund and the World Bank in Tokyo, I can certify that today, unlike four years ago, there is everywhere the firmest confidence in our ability to maintain the fixed relationship between gold and the dollar that anchors the entire international financial system . . .

The Treasury Department, through the Bureau of the Mint and licensed refiners and dealers, continued to buy virtually all newly mined gold from domestic mines and gold offered by foreign central banks and agencies at the official price of $35 per fine troy ounce (less 0.25 percent) plus mint charges for melting and refining. Similarly, gold was sold to licensed buyers by the Treasury at $35 (plus 0.25 percent) per ounce plus regular mint charges.

FOREIGN TRADE

Exports of gold continued to exceed imports by a wide margin for the fourth successive year. The value of net exports and imports for the 10-year period 1955–64 were as follows:

	Net imports (thousands)	*Net exports (thousands)*
1955–59 (average)	$173,785	--------
1960	333,385	--------
1961	--------	$718,790
1962	--------	230,030
1963	--------	159,370
1964	--------	381,856

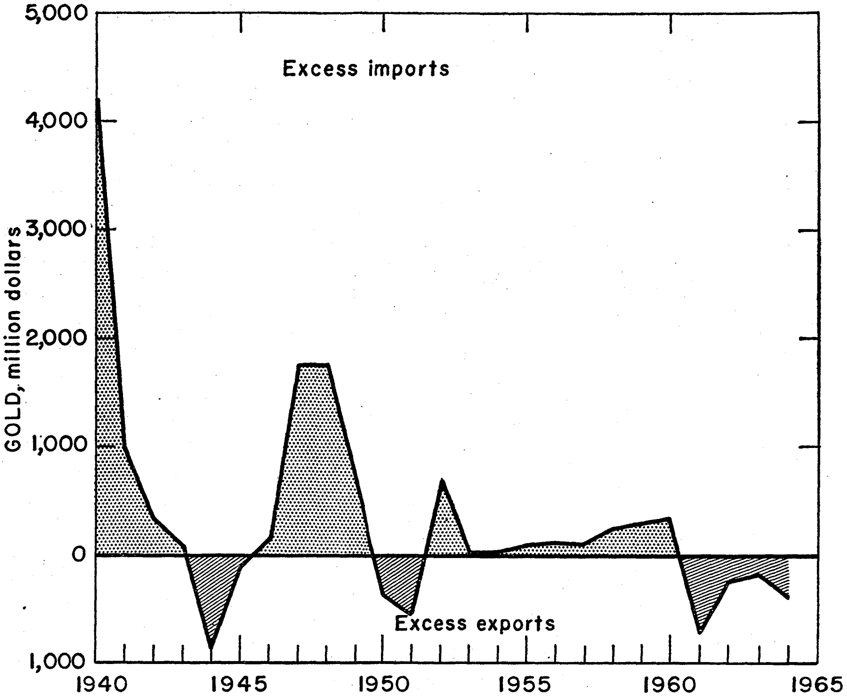

FIGURE 2.—Net imports or exports of gold.

TABLE 10.—U.S. imports of gold in 1964, by countries

Country	Ore and base bullion		Refined bullion	
	Troy ounces	Value	Troy ounces	Value
North America:				
Canada	67,936	$2,377,867		
El Salvador	390	13,650		
Honduras	3,319	116,151		
Mexico	16,414	572,190		
Nicaragua	82,778	2,879,793		
Panama	25	875		
South America:				
Bolivia	101	3,535		
Chile	23,013	806,796		
Colombia	251	8,800	445,490	$15,592,140
Ecuador	15,423	534,714		
Peru	22,330	779,629	66	2,310
Europe:				
Austria	51	1,785		
Belgium-Luxembourg	12,135	424,729		
Italy	13	455		
Norway	90	3,150		
United Kingdom	183	6,405	34,888	1,223,787
Asia:				
Japan	1,515	53,025	54,859	1,920,053
Korea, Republic of	92	3,233		
Philippines	46,067	1,612,348	318,615	11,151,642
Turkey	553	19,354		
Africa:				
Kenya	138	4,822		
Mozambique	3	105		
Rhodesia and Malawi	3	105		
South Africa, Republic of	785	27,473		
Oceania: Australia	21,066	737,275	293	10,255
Total	314,674	10,988,264	854,211	29,900,187

Source: Bureau of the Census.

TABLE 11.—U.S. exports of gold in 1964, by countries

Destination	Ore and base bullion		Refined bullion	
	Troy ounces	Value	Troy ounces	Value
North America: Canada	333	$11,619	284	$9,935
Europe:				
Belgium-Luxembourg	7,300	255,750		
France			12,056,481	421,976,761
Germany, West	1,335	46,587		
United Kingdom	12,598	440,930		
Asia: Ceylon			18	630
Oceania: Australia			58	2,040
Total	21,566	754,886	12,056,841	421,989,366

Source: Bureau of the Census.

TABLE 12.—Value of gold imported into and exported from the United States

(Thousand dollars)

Year	Imports	Exports	Year	Imports	Exports
1955–59 (average)	$220,807	$47,021	1962	$150,932	$380,962
1960	335,032	1,647	1963	44,414	203,784
1961	56,211	775,001	1964	40,888	422,744

Source: Bureau of the Census.

WORLD REVIEW

World gold output, excluding production in the Communist bloc countries, rose 1.9 million ounces to 46.1 million ounces valued at $1,613 million. The production gain in 1964 was the 11th consecutive annual increase and like last year was due almost entirely to continued expansion of mining operations in the Republic of South Africa, which nearly doubled production since 1955.

Gold production declined in most of the other principal gold-producing countries, but these losses were more than offset by the gain in South Africa.

Australia.—Mine output of gold declined for the fourth consecutive year. Production in Western Australia, the principal gold-producing State, dropped 11 percent.

Gold production in the Kalgoorlie district dropped, chiefly as a result of the closing of the Sons of Gwalia and Great Western Consolidated mines in 1963. Production declined at Lake View and Star, the largest mine, but the ore reserved was increased 800,000 tons to 3.6 million tons averaging 0.24 ounce per ton.

Central Norseman Gold Corp. treated 180,000 tons yielding 97,700 ounces of gold. The reserve increased 60,000 tons to 67,000 tons averaging 0.5 ounce per ton.

Great Boulder Gold Mines, Ltd., treated 530,000 tons of ore yielding 124,600 ounces of gold. The ore reserve declined to 2 million tons averaging 0.25 ounce per ton.

Mount Morgan, Ltd., the largest producer in Queensland, increased its output in the year ending June 30 to 70,200 ounces.

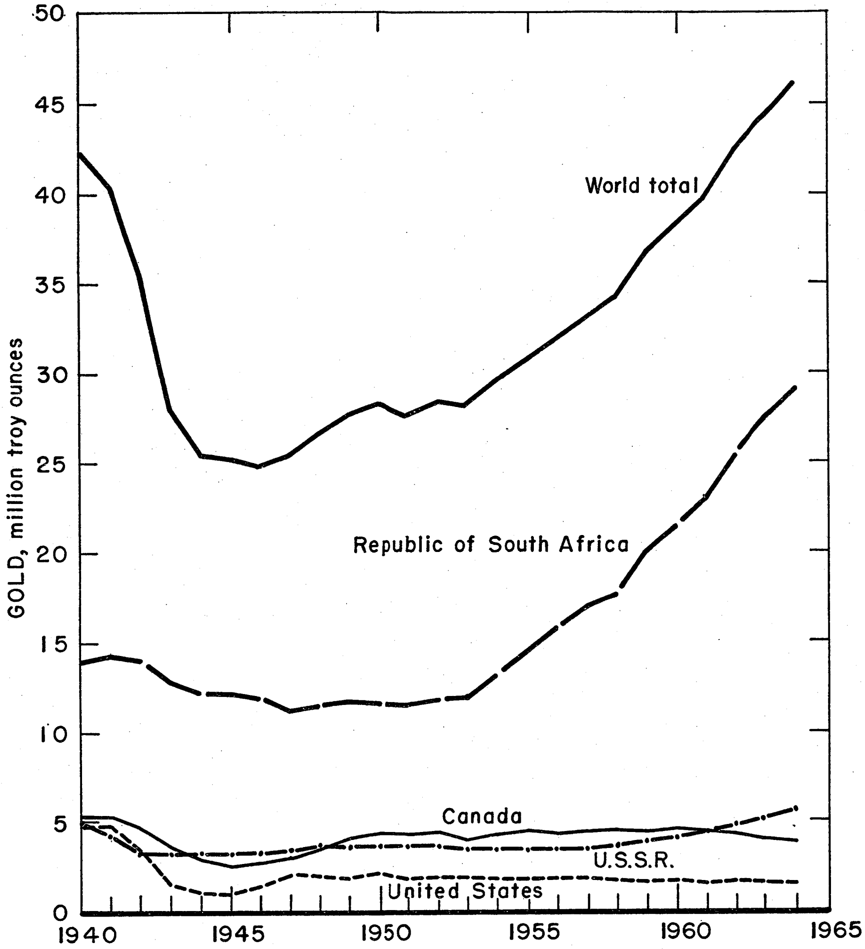

FIGURE 3.—World production of gold.

Canada.—Gold production in Canada dropped about 5 percent to 3.8 million ounces valued at Can$146.2 million. Canada continued to rank second among free world gold producers. The average Canadian mint price per ounce was $37.75, slightly higher than the $37.74 average in 1964. The price represented the equivalent in Canadian funds of the U.S. fixed price of $35 per ounce.

About 83 percent of the total gold output came from lode and placer mines; the remainder was recovered as a byproduct of base metal ores. Lode mine employment averaged about 14,300 persons.

All but 4 of 48 Canadian lode gold mines continued to receive cost aid under provisions of the Emergency Gold Mine Assistance Act. The act which has been in force since June 15, 1948, has been extended to the end of 1967. The act was designed to assist high-cost gold mines to continue operations and thus maintain existing gold-mining communities.

TABLE 13.—World production of gold by countries [1] [2]

(Troy ounces)

Country [1]	1955–59 (average)	1960	1961	1962	1963	1964 [p]
North America:						
Canada	4,482,896	4,628,911	4,473,699	4,178,396	3,972,047	3,810,738
Central America and West Indies:						
Costa Rica	[3] [4] 1,140	[e] 3,000	[e] 3,000	[e] 3,000	[e] 3,000	[e] 3,000
Cuba [3]	1,073	348	------	------	61	------
Dominican Republic	[4] 467	[3] 308	------	------	------	------
El Salvador	2,815	1,121	------	------	------	------
Guatemala	[e] 280	------	------	[3] 8	------	------
Haiti	------	[e] 1,400	4,341	7,149	6,778	[e] 5,900
Honduras	1,793	[3] 2,172	[3] 1,685	[3] 2,132	[3] 2,474	[3] 3,319
Nicaragua	218,267	210,200	226,250	221,984	204,769	211,900
Mexico	345,074	300,256	268,684	236,758	237,948	209,976
United States [5]	1,787,206	1,679,800	1,566,800	1,556,000	1,468,750	1,469,000
Total	6,841,000	6,828,000	6,544,000	6,205,000	5,896,000	5,714,000
South America:						
Argentina	5,902	3,504	2,251	965	482	303
Bolivia (exports)	29,821	45,457	80,184	35,052	153,033	50,043
Brazil [6]	116,225	118,893	118,636	127,092	131,979	134,326
British Guiana	15,400	2,364	1,702	1,903	2,847	2,111
Chile	89,784	54,367	56,489	65,009	77,290	65,620
Colombia	382,785	433,947	401,060	396,827	324,514	364,991
Ecuador	17,257	15,209	15,210	20,591	21,041	16,905
French Guiana	11,521	18,940	7,941	5,273	6,993	------
Peru [7]	160,216	141,001	137,418	122,985	101,019	85,809
Surinam	6,108	4,932	4,011	2,604	3,537	8,231
Venezuela	70,079	46,868	30,071	28,774	26,947	33,536
Total [e]	905,000	885,000	855,000	807,000	850,000	762,000
Europe:						
Finland	20,988	20,351	20,609	15,239	20,416	22,055
France	34,755	46,040	48,676	51,088	53,627	51,441
Germany, West	3,261	1,283	2,186	1,704	[e] 2,000	[e] 2,000
Greece	5,941	2,894	------	------	------	------
Italy	5,115	3,034	720	------	------	------
Portugal	22,544	21,927	22,377	21,927	21,895	21,219
Spain	12,662	13,986	8,231	6,687	15,625	23,824
Sweden	104,426	94,073	83,270	128,667	128,600	[e] 124,000
U.S.S.R. [e] [8] [9]	3,600,000	4,100,000	4,400,000	4,800,000	5,100,000	5,600,000
Yugoslavia	51,081	63,980	67,195	70,507	83,656	93,687
Total [e] [1]	4,000,000	4,700,000	5,000,000	5,500,000	5,800,000	6,400,000
Asia:						
Burma	162	304	194	[e] 200	[e] 200	[e] 200
Cambodia	[4] 1,810	4,180	4,180	965	6,687	[e] 6,000
China [e]	32,000	50,000	60,000	60,000	60,000	60,000
India	186,961	160,593	156,510	163,326	138,280	147,958
Indonesia	[e] 3,500	[e] 5,000	5,337	4,469	4,437	[e] 5,300
Japan	251,379	261,496	294,534	286,593	262,142	252,094
Korea:						
North [10]	136,000	160,000	160,000	160,000	160,000	160,000
South	60,384	65,814	84,105	106,548	90,095	75,779
Malaya	20,694	20,745	12,486	6,923	9,116	7,295
Philippines	406,141	410,618	423,983	423,394	376,006	425,770
Sarawak	1,052	3,326	4,132	2,885	2,773	3,115
Taiwan	23,329	15,702	17,619	24,026	31,710	17,660
Total [e] [1] [9]	1,120,000	1,160,000	1,225,000	1,240,000	1,140,000	1,160,000
Africa:						
Angola	32	42	48	77	37	7
Bechuanaland	351	203	261	288	142	10
Cameroon	2,980	416	537	775	1,874	[e] 1,000
Central Africa, Republic of	576	289	80	100	96	75
Congo, Republic of (Brazzaville)	6,724	2,628	3,376	3,718	2,958	3,567
Congo, Republic of the (Léopoldville)	361,396	14,145	233,672	203,707	214,574	125,742
Eritrea	6,205	5,144	5,529	2,315	[e] 2,300	[e] 2,300
Ethiopia	30,113	40,915	[e] 41,500	25,700	[e] 25,000	[e] 25,000
Gabon, Republic of	25,075	17,683	15,304	16,300	35,719	42,760
Ghana	776,253	[illegible]113	852,619	888,038	921,255	864,917

See footnotes at end of table.

TABLE 13.—World production of gold by countries [1] [2]—Continued

(Troy ounces)

Country [1]	1955-59 (average)	1960	1961	1962	1963	1964 [p]
Africa—Con.						
Kenya	9,531	8,645	12,299	9,327	10,193	12,475
Liberia [e]	670	1,119	2,088	2,184	1,960	1,824
Malagasy Republic	763	273	347	325	900	440
Morocco	907	104	136	----------	----------	----------
Mozambique	913	225	105	91	32	40
Nigeria	621	994	676	384	316	244
Rhodesia (formerly Southern)	543,933	562,703	570,095	554,647	566,277	575,386
Rwanda	3,651	1,566	900	[e]900	[e]500	[e]500
South Africa, Republic of	17,050,159	21,383,019	22,941,561	25,491,993	27,431,573	29,136,542
South-West Africa	----------	----------	----------	183	3	32
Sudan	1,755	2,116	1,226	[e]1,500	[e]900	877
Swaziland	52	806	1,325	2,214	2,092	2,078
Tanzania [11]	74,432	107,009	102,502	101,972	102,917	93,040
Uganda (exports)	337	744	453	412	16	----------
United Arab Republic (Egypt)	4,309	1,214	931	----------	----------	----------
Upper Volta	1,992	1,161	15,497	39,770	44,786	[e]33,200
Zambia	3,457	6,300	4,192	3,625	4,960	5,033
Total	18,907,000	23,350,000	24,810,000	27,350,000	29,370,000	30,930,000
Oceania:						
Australia	1,070,377	1,086,709	1,076,292	1,068,837	1,022,965	963,300
Fiji	74,417	72,203	83,417	87,354	107,262	100,493
New Guinea	62,309	45,019	41,789	39,007	43,552	38,934
New Zealand	28,888	33,326	28,294	21,742	14,206	8,948
Papua	489	132	31	45	47	43
Total	1,236,480	1,237,389	1,229,823	1,216,985	1,188,032	1,111,718
World total [e] [1]	33,000,000	38,200,000	39,700,000	42,300,000	44,200,000	46,100,000

[e] Estimate. [p] Preliminary.

[1] Gold is also produced in Bulgaria, Czechoslovakia, and Rumania but production data are not available; estimates for these countries are included in the total. East Germany, Hungary, and Thailand probably produce a negligible amount of gold. For some countries accurate figures are not possible to obtain owing to clandestine trade in gold (as, for example, in former French West Africa).

[2] This table incorporates some revisions. Data do not add exactly to totals shown because of rounding where estimated figures are included in the detail.

[3] Imports into the United States.

[4] Average annual production 1956–59.

[5] Refinery production.

[6] Mined gold only; production of alluvial gold unknown.

[7] Official government data include an estimate of 3,000 ounces of placer annually through 1963 and about 7,000 ounces in 1964. Actual placer production is believed to be nearer 22,000 ounces.

[8] In addition to the new figures shown for the years 1960–64, the following are the new figures (in millions of troy ounces) for earlier years: 1940, 5.1; 1941, 4.3; 1942, 3.3; 1943, 3.2; 1944, 3.2; 1945, 3.2; 1946, 3.3; 1947, 3.4; 1948, 3.6; 1949, 3.6; 1950, 3.6; 1951, 3.6; 1952, 3.6; 1953, 3.5; 1954, 3.5; 1955, 3.5; 1956, 3.5; 1957, 3.5; 1958, 3.6; and 1959, 3.9.

[9] Output from U.S.S.R. in Asia included with U.S.S.R. in Europe.

[10] Estimate according to Minerais et Metaux (France), except 1964.

[11] Including gold in lead concentrates exported amounting to: 9,709 ounces, 1955–59 (average); 8,963 ounces in 1960; 521 ounces in 1961; and none since.

Kerr-Addison Mines, Ltd., the leading gold producer, reported that gold output declined 18 percent to about 267,000 ounces valued at $10.1 million. The average daily milling rate was reduced 18 percent to 2,129 tons per day, but average recovered value increased from $12.76 to $12.96 per ton. Total production cost was $9.13 per ton compared with $8.23 in 1963, indicating a net operating profit of $3.83 per ton. The proven ore reserve at yearend was 5.4 million tons averaging 0.43 ounce per ton compared with 6.0 million tons averaging 0.42 ounces at the end of 1963.[5]

Hollinger Consolidated Gold Mines, Ltd., produced bullion from its operations at the Hollinger and Ross mines, valued at $10.9 million, compared with $10.2 million in 1963. Operating costs decreased from $10.8 million to $10.6 million. Financial assistance received under the Emergency Gold Mine Assistance Act totaled $530,600.[6]

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[5] Kerr-Addison Mines, Ltd. Annual Report 1964.

The Yukon Consolidated Gold Corp., Ltd., operated six dredges and one combined hydraulic and mechanical operation in the Dawson area of the Yukon Territory. Company dredges handled about 4 million cubic yards of gravel yielding gold valued at $1.4 million, a moderate decline from 1963 production. Average recovery per cubic yard was 34.3 cents at a cost of 32.3 cents, compared with recovery of 31.5 cents at a cost of 28.5 cents in 1963. The proved gravel reserve at yearend was 7.3 cubic yards averaging 43.2 cents per yard.[7]

TABLE 14.—Canada: Geographical distribution of gold production

(Troy ounces)

Province or Territory	1963	1964 p
Alberta	132	55
British Columbia	159,473	132,642
Manitoba	49,886	55,919
New Brunswick	1,128	1,440
Newfoundland	12,318	18,679
Northwest Territories	387,000	398,133
Nova Scotia	----	63
Ontario	2,338,854	2,135,269
Quebec	917,229	944,941
Saskatchewan	64,813	47,692
Yukon Territory	55,211	75,905
Total	3,986,044	3,810,738

p Preliminary.

Source: Dominion Bureau of Statistics.

Colombia.—Output of gold increased 13 percent to nearly 365,000 ounces. Of this total, International Mining Corp. produced 134,000 ounces from underground and dredging operations, 9 percent more than in 1963. Although the quantity of gravel dredged and gold recovered dropped because one dredge was inoperative during part of the year, ore mined from underground operations increased sharply, reflecting settlement of a labor strike.

Four dredges were operated in the Choco district and one in Narino. Dredging reserves increased to 108.0 million cubic yards, averaging 15.6 cents per yard at yearend, compared with 88.8 million cubic yards averaging 16.2 cents per yard at the end of 1963. The underground reserve dropped to 177,000 tons averaging 0.81 ounces per ton from 301,000 tons averaging 0.72 at the end of 1963. Gold sales averaged $36.28 per ounce as a result of a 15 peso ($1.18) per ounce subsidy begun in August by the Bank of the Republic.

Pato Consolidated Gold Dredging, Ltd., operated seven dredges in Antioquia treating 27.2 million cubic yards of gravel with an average unit value of 13.59 cents per cubic yard dredged. The minable reserve at yearend was estimated to be 364.9 million cubic yards averaging 16.15 cents per yard.[8]

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[6] Hollinger Consolidated Gold Mines, Ltd. Annual Report covering operations for the year 1964, p. 6.

[7] The Yukon Consolidated Gold Corp., Ltd. President's Statement 1964.

[8] Pato Consolidated Gold Dredging, Ltd. 31st Annual Report 1964.

Ghana.—Gold production in Ghana declined 6 percent, although Ashanti Goldfields Corp., Ltd. reported a record output for the eighth consecutive year. The corporation milled 489,610 tons yielding 471,420 ounces, more than one-half of the country's total output. Ashanti's ore reserves increased to 3.3 million tons averaging 20 pennyweight per ton also a record high equivalent to more than 6 years at the current milling rate. The Government granted the mining industry exemption from the sales tax on supplies and equipment.

A new government holding company, the Ghana State Gold Mining Corp., was formed to succeed the State Mining Corp. in the control of government-owned mines: Amalgamated Banket Areas (A.B.A.), Ariston, Ghana Main Reef, Bibiani, and Bremang Gold Dredging.

Philippines.—Gold production increased about 13 percent to 425,800 ounces, reflecting uninterrupted operations at Benguet Consolidated, Inc., the leading producer, and increased recovery of byproduct gold from copper ore at Lepanto Consolidated Mining Co., Ltd. Operating costs at Benguet rose ₱0.46 ($0.12) per ounce to ₱174.91 ($44.85). Baguio Gold Mining Co.'s production was valued at ₱3.3 million ($0.85 million), up slightly from 1963. Production at benguet Exploration, Inc., was valued at ₱5.0 million ($1.3 million).

Southern Rhodesia.—Gold production in Southern Rhodesia increased about 2 percent to a post-World War II high of 575,400 ounces. Most of the increase came from the larger mines such as the Dalney, the country's second largest producer. Production from Cam and Motor, the largest mine, operated by the Rio Tinto group, declined and the mine is nearing the end of its life.

The Government assistance plan has stimulated exploration of several inactive mines and mining properties that are expected to lead to increased gold output. Loans were granted to cover working losses up to 10 percent of revenue and for approved capital expenditures. A maximum subsidy of £3 ($8.40) per ounce was paid to marginal producers.

South Africa, Republic of.—Output of gold in South Africa increased 6 percent, again establishing a record high of 29.1 million ounces valued at $1,019 million. South African production constituted nearly 72 percent of the total free world gold production.

Of 57 operating mines that were members of the Transvaal and Orange Free State Chamber of Mines, 52 were primary gold producers and 7 were primary uranium producers. Two older mines, Simmer and Jack, and Brakpan, ceased operations during the year. Estimated ore reserves increased 6.4 million tons to 180.4 million tons averaging 8.59 ounces per ton. The average number of employees in the gold-mining industry declined to 45,770 Europeans and 380,950 Africans.

Anglo-American Corporation of South Africa, Ltd., reported that the 12 mines of its group produced 10.6 million ounces of gold valued at $374 million compared with 9.4 million ounces valued at $330 million in 1963. Group mines contributed about 36 percent of the country's total production, and nearly 26 percent of the free world output of gold. Western Deep Levels, Ltd., continued to expand production. The ore reserve at yearend was 4.4 million tons averaging 0.48 ounces per ton compared with 4.5 million tons averaging 0.39 ounces per ton at the end of 1963.[9]

Free State Geduld Mines, Ltd., increased production and profits substantially. The ore reserve at yearend was 4.3 million tons with an average value of 1.37 ounces per ton, compared with 4.1 million tons with an average value of 1.34 ounces per ton at the end of 1963. Production declined moderately at the President Brand operation. The yearend ore reserve was 5.7 million tons averaging 0.69 ounce per ton compared with 5.1 million tons averaging 0.73 ounce per ton at yearend 1963.

Consolidated Gold Fields of South Africa, Ltd., reported that its group of gold and gold-uranium mines in fiscal year 1964 increased gold production 5 percent to 5.2 million ounces, a new record gold output. The gain in output resulted chiefly from restoration of full-scale operations at West Dreifontein Gold Mining Co., Ltd., following reconstruction of the reduction plant. The Gold Fields group of mines treated 13.0 million tons of ore yielding 0.38 ounce per ton ($13.30) compared with 12.9 million tons yielding 0.36 ounce per ton ($12.60) in fiscal year 1963. Working costs per ounce decreased 54 cents to $21.62; working profits increased moderately. West Driefontein treated 2.6 million tons of ore and achieved a record production of 2.0 million ounces. Average grade of ore was 0.77 ounce per ton ($26.88); average working cost was $12.98 per ton.

Union Corp., Ltd., reported a continued gain in ore milled and gold produced from its group of mines, chiefly due to increased yield at the two new mines in the Evander area, Braken and Leslie, and the St. Helena mine in the Orange Free State. The Union Corp. group milled 13.2 million tons of ore yielding 4.0 million ounces. The ore reserve was increased 2.5 million tons to 39.5 million tons. The Braken mine milled 1.1 million tons yielding $16.08 per ton at a working cost of $7.34 per ton. The ore reserve at yearend was 2.9 million tons averaging 0.52 ounce per ton over a 38-inch stoping width. The Leslie mine milled 1.8 million tons yielding $11.60 per ton at a working cost of $6.20 per ton. The ore reserve at yearend was 4 million tons averaging 0.37 ounce ($12.95) per ton over a stoping width of 44 inches. At the St. Helena mine, milling rate declined slightly to 2.4 million tons, but average yield per ton increased $0.90 to $15.72 at a working cost of $5.66 per ton. The yearend ore reserve was 8.9 million tons averaging about 0.51 ounce per ton ($17.50) across a stoping width of 59 inches. At the East Geduld mine, tons milled (1.4 million tons) and averaged yield ($8.85) continued to decline, and working costs ($5.63) continued to rise. The ore reserve in the Main and Kimberley Reefs totaled 2.9 million tons, averaging about 0.25 ounce per ton ($8.75).[10]

U.S.S.R.—No data on gold production were published by the U.S.S.R. The revised estimates of mine production for the U.S.S.R. appearing in table 13 are based on substantial new information on gold-mining activity in the Soviet Union, which has become available to the Bureau of Mines since earlier Minerals Yearbooks were published. The new information, however, is limited and further revisions in the estimates may be expected in future years as more definitive information of the magnitude of the Soviet gold-mining industry becomes available.

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[9] Anglo-American Corporation of South Africa, Ltd. 48th Annual Report. 1964, pp. 8, 17, and 63–67.

[10] Union Corp., Ltd. Report and Accounts for the Year ended 31st December 1964. Pp. 24–29.

TECHNOLOGY

Two new electroplating processes using low-karat gold alloys were developed by Sel-Rex Corp., Nutley, N.J., The new processes are reported to reduce the cost of gold in electroplates and expand its application in industrial and consumer products. Normally, electroplated gold contains 95 to 99 percent gold, but the new electroplated alloys contain as little as 75 percent.

One of the new processes Alautronex 18, deposits a 70 to 80 percent yellow gold alloy and is reported to be more than twice as hard as conventional gold without appreciable loss of electrical conductivity. The other process, Autronex W, produces a 70 to 80 percent white gold plate, is said to be more than six times harder than conventional gold plates, and to have superior corrosion and wear resistance. The increased coverage per unit weight of gold using the new processes reduces the amount of gold required for a given plating thickness by 40 percent.

Gold-aluminum alloys that combine oxidation resistance with mechanical stability and decreased plastic flow were described in a research report by the Office of Technical Services.[11] Electrodeposition of aluminum oxide in gold from electrolytes operating at pH values between 5 and 12 resulted in an appreciable decrease in the creep rate of 400° to 600° F. Aluminum oxide Al_2O_3 content up to 4.36 percent by volume did not change resistivity or impair the corrosion resistance of gold.

An electroless gold-plating process developed by Sel-Rex Corp. was reported to have much greater stability than other baths commercially available. The new process which deposited 99.99 percent gold in thicknesses of 2.5 microns per hour can be used effectively in plating the inside of small diameter tables used in microelectronic circuitry.

Patents were issued for plating bright gold from gold cyanide solution using stable nickel and cobalt chelates.[12]

An ion-exchange technique for the recovery of gold from cyanide solution was described. Copper and zinc in solution which decrease exchange capacity for gold can be desorbed differentially with hydrochloric acid in potassium cyanide. The gold and silver are desorbed from the resin with thiourea and hydrochloric acid. The gold is precipitated by cementation on powdered lead and the thiourea recirculated. Gold recovery is 98 to 99 percent.

In cyaniding gold-arsenic concentrate, tests in Russia showed that pretreatment of the roasted calcine with sulfuric acid at 90° C. for 30 minutes increased gold recovery from about 80 percent to 96.9 percent due to removal of iron arsenates and oxides from gold surfaces.[13]

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[11] Office of Technical Services, U.S. Dept. of Commerce. Electrodeposition of Dispersion-Strengthened Gold—Al_2O_3—Alloys. December 1963, 11 pp., AD 435 622.

[12] Parker, Edward A., Cranston Powers, and James A. Powers (assigned to Technic, Inc., Providence, R.I.). Acid Gold Plating; Bright Gold Plating Process. U.S. Patents 3,149,057 and 3,149,058.

[13] Brien, Frederick B. Foreign Developments and Research Activities. Min. Eng., v. 17, No. 2, February 1965, pp. 118D–119.

The California Institute of Technology announced creation of a gold-germanium superconducting alloy by an ultrafast cooling technique which opens the way to developing other alloys with useful electrical and magnetic properties. Ultrarapid cooling of the molten mixture of gold and germanium quickfreezes the melt in which the mixed atoms form into a pattern with new chemical bonding properties and a much finer grain structure. This compound is superconductive.

The preparation, characteristics, and principal uses of gold compounds, gold alloys, and gold leaf in industry and the arts were described in a technical journal.[14]

A process to recover gold from sea water by using chelating agents was sucessfully tested by Professor Ernst Bayer of Tubingen University, West Germany.[15] An aminophenol type chelate polymer containing sulfur extracted 1.4 micrograms gold from 100 liters of Bay of Naples water corresponding exactly to the gold content of the water determined prior to extraction. The 1.4 microgram gold content (45×10^{-9} troy ounces) is equivalent to about 1,875 ounces per cubic mile.

Methods of determining accurately the recoverable gold and silver content in ores and placers and the most economical processes for extracting these metals in marketable form were described.[16] Sampling and laboratory testing techniques were discussed and their application to various types of ores under operating conditions appraised.

Problems encountered in treating gold ores by cyaniding and in adjusting conditions to maximize the rate of dissolution of gold while minimizing the rates of dissolution of other minerals were described in a technical journal.[17] The methods of controlling cyanidation conditions in mill operation involve determining optimum grind, alkalinity, cyanide concentration, oxygen concentration, and contact time. Some instruments used in applying chemical controls were described.

Concentrated mining methods, adopted at some new mines in South Africa, appeared to be the most efficient system where the gold content is high and adequate capital is available to permit rapid development and production. Application of these advanced techniques at Zandpan Gold Mines in the Klerksdorp were described.[18]

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[14] Sanderson, L. Gold—Its Compounds Uses, Pt. 2. Canadian Min. J., v. 85, No. 5, May 1964, pp. 81, 84–85.

[15] Chemistry. Gold From the Oceans. V. 37, No. 10, October 1964, pp. 24–25.

[16] Thom, Clarence. Testing Gold and Silver Ores. Deco Trefoil, May–June–July 1964, pp. 9–20.

[17] Downes, K. W. Controls in the Cyanide Process. Canadian Min. J., v. 85, No. 10, October 1964, pp. 92–95.

[18] Canadian Mining Journal. South Africa. V. 85, No. 7, July 1964, pp. 19, 22, 26.

Graphite

By John W. Cole[1]

◆

THE HIGH rate of domestic industrial activity throughout the year was reflected by increased consumption of all types of natural graphite except Ceylon amorphous (crystalline) which declined slightly because of substitution of other types of lower-cost graphite. World production decreased chiefly because of a decrease in production from South Korea. Austrian production increased for the third consecutive year.

TABLE 1.—Salient graphite statistics

	1955–59 (average)	1960	1961	1962	1963	1964
United States:						
Consumption short tons	39,100	37,300	35,700	44,400	47,000	54,000
Value thousands	$5,429	$4,773	$4,651	$5,648	$6,111	$7,026
Imports for consumption short tons	40,500	48,300	29,700	39,500	52,200	47,200
Value thousands	$1,963	$1,755	$1,332	$1,783	$2,000	$1,944
Exports short tons	1,300	1,900	1,600	1,200	900	2,000
Value thousands	$200	$289	$257	$223	$190	$333
World: Production short tons	350,000	r 480,000	r 455,000	590,000	r 780,000	600,000

r Revised.

DOMESTIC PRODUCTION

The Southwestern Graphite Co., Burnet, Tex. continued to produce crystalline flake graphite.

Manufactured (artificial) graphite products were produced by companies as follows:

Union Carbide Corp., Carbon Products Division	Niagara Falls, N.Y. Clarksburg, W. Va. Columbia, Tenn.
Great Lakes Carbon Corp	Niagara Falls, N.Y. Morganton, N.C. Antelope Valley, Calif.
International Graphite & Electrode Division, Speer Carbon Co.	St. Marys, Pa. Niagara Falls, N.Y.
Stackpole Carbon Co	St. Marys, Pa.
Basic Carbon Corp	Sanborn, N.Y.
Pure Carbon Co., Inc	St. Marys, Pa.
Ultra Carbon Corp	Bay City, Mich.
Poco Graphite Co	Dallas, Tex.
The Dow Chemical Co	Midland, Mich.
General Electric Co., Metallurgical Products Dept.	Detroit, Mich.

Basic Carbon Corp., one of the leading producers of carbon and graphite cloth and yarn, and Falls Industries, Inc., fabricator of heat exchangers and other corrosion resistant graphite equipment, were sold by Basic, Inc. to The Carborundum Co., Niagara Falls, N.Y.

CONSUMPTION AND USES

Demand for natural graphite in 1964 was 15 percent greater than in 1963. Flake consumption rose 13 percent and use of amorphous graphite rose 19 percent. Ceylon amorphous (crystalline) use declined 10 percent.

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[1] Commodity specialist, Division of Minerals.

The large tonnage use of manufactured graphite continued to be electrodes for the electrosmelting industries and anodes for the electrochemical industries.

TABLE 2.—Consumption of natural graphite in the United States

Year	Short tons	Value	Year	Short tons	Value
1955–59 (average)	39,147	$5,428,900	1962	44,383	$5,648,000
1960	37,289	4,773,400	1963	47,006	6,110,900
1961	35,652	4,651,200	1964	54,043	7,026,300

TABLE 3.—Consumption of natural graphite in the United States in 1964, by uses

Use	Crystalline flake		Ceylon amorphous		Other amorphous [1]		Total	
	Short tons	Value	Short tons	Value	Short tons	Value	Short tons	Value
Batteries	W	W	-------	-------	989	$90,039	989	$90,039
Bearings	W	W	W	W	218	92,823	218	92,823
Brake linings	485	$131,074	320	$83,947	855	118,011	1,660	333,032
Carbon brushes	155	75,151	229	127,257	166	23,122	550	225,530
Crucibles, retorts, stoppers, sleeves, and nozzles	[2] 3,901	625,453	W	W	W	W	3,901	625,453
Foundary facings	1,886	346,379	582	108,989	17,206	1,467,377	19,674	1,922,745
Lubricants	1,636	351,788	2,377	486,629	2,924	335,881	6,937	1,174,298
Packings	236	113,138	7	6,678	365	65,500	608	185,316
Paints and polishes	W	W	W	W	500	41,258	500	41,258
Pencils	862	257,706	468	161,774	457	59,121	1,787	478,601
Refractories	W	W	-------	-------	6,328	645,654	6,328	645,654
Rubber	44	20,615	111	14,808	36	11,992	191	47,415
Steelmaking	566	96,833	234	11,479	7,766	660,587	8,566	768,899
Other [3]	422	142,207	135	39,302	1,577	213,772	2,134	395,281
Total	10,193	2,160,344	4,463	1,040,863	39,387	3,825,137	54,043	7,026,344

W Withheld to avoid disclosing individual company confidential data.

[1] Includes small quantities of crystalline flake and Ceylon amorphous, and mixtures of natural and manufactured graphite.

[2] Includes some amorphous.

[3] Includes adhesives, catalyst manufacture, chemical equipment and processes, electronic products, powdered-metal parts, small packages, specialties, and other uses not specified.

PRICES

Actual prices for natural graphite are negotiated between buyer and seller on the basis of a wide range of specifications.

Prices quoted per pound of crystalline flake graphite by Oil, Paint and Drug Reporter follow: 88 to 90 percent carbon, 20 to 23.5 cents; 90 to 92 percent carbon, 22.5 to 25.5 cents; 95 to 96 percent carbon, 29 to 32 cents; and No. 1 and 2 flake, 90 to 95 percent carbon, 29 to 32 cents. Amorphous-crystalline, 97 percent carbon, was quoted at 30.5 to 33 cents. Quotations for amorphous ranged from 6.5 to 12 cents. Quotations covering all grades increased 1 to 2 cents over quotations during 1963.

Prices shown by E&MJ Metal and Mineral Markets for flake and crystalline graphite, f.o.b. source, bags, per ton, were Malagasy Republic, $82 to $181; Norway $77 to $131; and West Germany, $113 to $610. Ceylon graphite was listed at $85 to $223 per ton. Amorphous graphite was quoted as follows: Mexico (bulk) per ton, $15 to $18; South Korea (bulk) per ton, $14; and Hong Kong (bags) per ton $20.

FOREIGN TRADE

Although the quantity of natural graphite imported totaled 9 percent less than in 1963, the value decreased only 3 percent because the tonnage decrease was in low-value Mexican amorphous graphite while imports of high-value graphite from Ceylon increased.

TABLE 4.—U.S. imports for consumption of natural and artificial graphite, by countries

Year and country	Crystalline				Amorphous				Total	
	Flake		Lump, chip, or dust		Natural		Artificial			
	Short tons	Value	Short tons	Value	Short tons	Value	Short tons	Value	Short tons	Value
1955–59 (average)	5,708	$693,845	122	$24,828	34,566	$1,240,053	71	$4,699	40,467	$1,963,425
1960	3,753	340,753	121	36,630	44,265	1,321,137	185	56,952	48,324	1,755,472
1961	4,377	428,793	55	17,138	25,246	863,457	70	22,787	29,748	1,332,175
1962	5,458	532,270	181	55,769	29,250	1,100,072	4,639	95,274	39,528	1,783,385
1963:										
North America:										
Mexico	------	--------	------	--------	39,724	766,229	302	5,912	40,026	772,141
Europe:										
Austria	------	--------	------	--------	10	868	------	--------	10	868
France	16	7,340	------	--------	--------	----------	------	--------	16	7,340
Germany, West	331	61,127	165	51,450	898	102,686	------	--------	1,394	215,263
Norway	------	--------	------	--------	2,652	220,515	33	2,183	2,685	222,698
Switzerland	------	--------	------	--------	--------	----------	6	2,448	6	2,448
United Kingdom	------	--------	------	--------	71	8,077	28	1,983	99	10,060
Asia:										
Ceylon	------	--------	------	--------	2,467	278,566	------	--------	2,467	278,566
Hong Kong	------	--------	------	--------	112	2,400	------	--------	112	2,400
Korea, South	------	--------	------	--------	194	4,099	------	--------	194	4,099
Turkey	55	5,592	------	--------	--------	----------	------	--------	55	5,592
Africa: Malagasy Republic	5,087	468,315	33	10,290	--------	----------	------	--------	5,120	478,605
Total	5,489	542,374	198	61,740	46,128	1,383,440	369	12,526	52,184	2,000,080
1964:										
North America:										
Canada	2	569	------	--------	88	3,046	49	2,470	139	6,085
Mexico	------	--------	------	--------	33,709	653,515	------	--------	33,709	653,515
Europe:										
Austria	------	--------	------	--------	6	1,352	------	--------	6	1,352
France	11	4,370	------	--------	--------	----------	------	--------	11	4,370
Germany:										
East	------	--------	------	--------	16	1,755	------	--------	16	1,755
West	215	40,364	66	20,580	1,585	179,443	4	697	1,870	241,084
Netherlands	------	--------	------	--------	1	843	------	--------	1	843
Norway	13	1,402	------	--------	2,543	203,948	------	--------	2,556	205,350
Switzerland	------	--------	------	--------	--------	----------	3	1,224	3	1,224
United Kingdom	------	--------	------	--------	58	1,146	------	--------	58	1,146
Asia:										
Ceylon	------	--------	------	--------	3,215	364,275	------	--------	3,215	364,275
Hong Kong	------	--------	------	--------	336	6,900	------	--------	336	6,900
Japan	243	22,634	------	--------	--------	----------	------	--------	243	22,634
Korea, South	------	--------	------	--------	617	12,525	------	--------	617	12,525
Thailand	------	--------	------	--------	34	2,424	------	--------	34	2,424
Africa:										
Cameroon	------	--------	------	--------	34	2,424	------	--------	34	2,424
Malagasy Republic	4,263	408,144	------	--------	84	7,755	------	--------	4,347	415,899
Total	4,747	477,483	66	20,580	42,326	1,441,351	56	4,391	47,195	1,943,805

Source: Bureau of the Census.

TABLE 5.—U.S. exports of natural graphite, by countries

Year and destination	Amorphous		Crystalline flake, lump, or chip		Natural n.e.c.[1]		Total	
	Short tons	Value	Short tons	Value	Short tons	Value	Short tons	Value
1963:								
North America:								
Canada	123	$22,520	63	$21,570	-	-	186	$44,090
Canal Zone	-	-	-	-	1	$500	1	500
Costa Rica	-	-	(2)	208	1	580	1	788
Dominican Republic	-	-	(2)	230	-	-	(2)	230
Honduras	(2)	202	-	-	-	-	(2)	202
Mexico	6	2,521	10	5,680	37	14,522	53	22,723
Trinidad and Tobago	-	-	2	788	-	-	2	788
South America:								
Argentina	2	684	-	-	10	3,063	12	3,747
Chile	-	-	4	960	-	-	4	960
Colombia	-	-	18	3,346	2	1,164	20	4,510
Ecuador	-	-	2	410	-	-	2	410
Peru	-	-	6	2,398	1	236	7	2,634
Venezuela	-	-	14	3,327	33	9,306	47	12,633
Europe:								
Denmark	-	-	1	605	-	-	1	605
France	34	7,447	2	1,201	32	6,142	68	14,790
Italy	-	-	1	934	1	616	2	1,550
Netherlands	-	-	-	-	1	620	1	620
Sweden	4	778	-	-	-	-	4	778
United Kingdom	336	49,016	-	-	13	1,604	349	50,620
Asia:								
India	8	1,664	-	-	-	-	8	1,664
Israel	-	-	-	-	1	530	1	530
Japan	3	1,372	-	-	-	-	3	1,372
Pakistan	10	1,924	-	-	-	-	10	1,924
Philippines	5	766	6	4,375	3	900	14	6,041
Oceania: Australia	2	468	15	3,420	86	11,536	103	15,424
Total	533	89,362	144	49,452	222	51,319	899	190,133
1964:								
North America:								
Canada	918	118,334	48	17,810	-	-	966	136,144
El Salvador	-	-	4	774	-	-	4	774
Honduras	2	202	-	-	-	-	2	202
Mexico	2	1,300	22	12,069	13	3,958	37	17,327
South America:								
Argentina	8	3,518	-	-	5	994	13	4,512
Bolivia	-	-	10	2,076	-	-	10	2,076
Brazil	84	17,869	-	-	192	35,349	276	53,218
Chile	-	-	2	528	13	3,222	15	3,750
Colombia	-	-	12	3,688	-	-	12	3,688
Ecuador	-	-	1	298	-	-	1	298
Peru	-	-	34	3,548	-	-	34	3,548
Venezuela	22	4,040	74	14,833	17	3,595	113	22,468
Europe:								
Czechoslovakia	11	1,984	-	-	-	-	11	1,984
Denmark	11	2,061	-	-	-	-	11	2,061
France	38	8,300	-	-	88	11,636	126	19,936
Germany, West	6	936	-	-	-	-	6	936
Italy	-	-	-	-	2	516	2	516
Netherlands	-	-	(2)	650	3	620	3	1,270
Sweden	10	1,921	-	-	-	-	10	1,921
United Kingdom	142	19,629	-	-	9	2,138	151	21,767
Asia:								
India	13	2,546	-	-	-	-	13	2,546
Iran	-	-	3	778	-	-	3	778
Pakistan	14	2,674	-	-	-	-	14	2,674
Philippines	20	5,471	-	-	20	5,793	40	11,264
Saudia Arabia	-	-	1	968	1	608	2	1,576
Africa: South Africa, Republic of	-	-	8	1,866	-	-	8	1,866
Oceania: Australia	25	3,592	10	2,308	46	8,477	81	14,377
Total	1,326	194,377	229	62,194	409	76,906	1,964	333,477

[1] Not elsewhere classified.
[2] Less than ½ ton.

Source: Bureau of the Census.

According to the Bureau of the Census 33,316 short tons of carbon and graphite electrodes valued at $5,494,944 were imported. Principal countries of origin were: Italy, 20,355 tons valued at $1,806,215; Japan, 7,667 tons valued at $2,582,566; and France, 4,395 tons valued at $862,215.

WORLD REVIEW

A summary survey of the natural graphite industry of the world was published.[2] In addition to summary statistics covering world distribution, production, and uses of natural graphite, one section describes the use of graphite as a moderator and reflector for nuclear reactors. A summary review of results of efforts by European companies to produce nuclear grade graphite from natural graphite, first published in 1955 by the Conference on Peaceful Uses of Atomic Energy, is given.

TABLE 6.—World production of natural graphite by countries [1] [2]

(Short tons)

Country [1]	1955-59 (average)	1960	1961	1962	1963	1964 [p]
North America: [1]						
Canada	----------	----------	1	----------	----------	13
Mexico	28,637	37,827	19,846	31,992	33,065	[e] 33,000
South America:						
Argentina	440	538	858	468	229	[3] 229
Brazil	996	1,430	1,592	1,775	[4] 1,775	[4] 1,775
Europe: [1]						
Austria	32,775	97,043	89,255	98,416	109,778	112,697
Germany, West	12,278	12,760	13,349	13,134	[e] 13,000	[e] 13,000
Italy	3,346	4,098	4,484	3,703	1,884	1,443
Norway	5,624	6,437	6,300	7,222	8,400	[3] 8,400
Spain	334	288	303	----------	----------	----------
Sweden	433	----------	----------	----------	----------	----------
U.S.S.R. [e]	47,000	50,000	55,000	60,000	60,000	60,000
Asia:						
Ceylon (exports)	9,141	10,107	10,016	9,665	9,280	11,947
China [e]	33,000	45,000	45,000	45,000	45,000	45,000
Hong Kong	3,103	4,255	1,865	902	891	795
India	362	(5)	1,830	(5)	(5)	(5)
Japan	4,148	4,979	3,836	3,812	3,305	2,700
Korea:						
North [e]	32,000	68,000	72,000	72,000	77,000	77,000
South	104,814	101,777	98,892	204,032	374,428	[e] 195,000
Africa:						
Kenya	658	1,113	----------	----------	----------	----------
Malagasy Republic	15,584	15,923	16,473	19,274	21,214	[6] 17,413
Morocco	80	----------	----------	----------	----------	----------
South Africa, Republic of	1,387	894	963	1,308	671	1,042
South-West Africa	202	----------	----------	----------	----------	275
Tanganyika	11	26	----------	----------	----------	----------
Oceania: Australia	7	----------	----------	----------	----------	----------
World total (estimate) [1] [2]	350,000	480,000	455,000	590,000	780,000	600,000

[e] Estimate. [p] Preliminary.

[1] Graphite has been produced in Czechoslovakia, but production data are not available; estimates by author of chapter included in total. U.S. figure withheld to avoid disclosing individual company confidential data, included in world total.

[2] This table incorporates some revisions. Data do not add exactly to totals shown because of rounding where estimated figures are included in the detail.

[3] 1963 data.

[4] 1962 data.

[5] Data not available; estimate by author of chapter included in total.

[6] Exports.

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[2] Tron, A. R. (Department of Scientific and Industrial Research, Warren Spring Laboratory) The Production and Uses of Natural Graphite. H.M. Sta. Off., London, 1964, 83 pp.

Canada.—Great Lakes Carbon Corp. (Canada) Ltd., announced plans to expand its graphite manufacturing facilities at Berthierville, Quebec. Four graphitizing furnaces will be added with provision for four additional units to be added at a later date.

Ceylon.—Shipments of graphite by the two major firms regularly exporting to the United States are shown as follows:

TABLE 7.—Ceylon: Exports of graphite to the United States, by grades, in 1964

Grade:	*Short tons*	*Value per ton*
97 percent carbon or higher	1,238	$137.70
90 to 96 percent carbon	1,322	98.60
Less than 90 percent carbon	420	91.00
Total	2,980	113.80

TABLE 8.—Ceylon: Exports of graphite, by countries

(Short tons)

Destination	1963	1964
North America:		
Canada	84	29
United States	2,670	3,430
Europe:		
Belgium	59	54
France	215	543
Germany, West	53	72
Netherlands	22	----
Poland	51	186
United Kingdom	2,555	2,702
Asia:		
India	702	1,243
Japan	2,004	2,659
Pakistan	218	289
Philippines	2	22
Syria	49	----
Thailand	37	17
Oceania: Australia	538	688
Other countries	21	23
Total	9,280	11,957

TABLE 9.—Malagasy Republic: Exports of graphite, by countries

(Short tons)

Destination	1962	1963
North America: United States	5,494	5,306
Europe:		
Belgium-Luxembourg	55	95
Denmark	11	55
France	3,033	3,334
Germany:		
East	123	----
West	2,741	2,362
Italy	1,290	1,246
Netherlands	----	85
Poland	----	22
Spain	209	232
United Kingdom	4,135	3,729
Asia:		
India	----	47
Japan	871	538
Oceania: Australia	179	344
Other countries	6	18
Total	18,147	17,413

Japan.—The Artificial Graphite Electrode Export Co. of Japan signed an agreement with the Soviet Union for the sale of a 4,500-ton-per-year graphite electrode plant at a reported price of $420 per ton capacity.

South-West Africa.—Production of graphite from a small deposit 25 miles south of Kubis station on the Luderditz-Kertmanshoop Railway line amounted to 20 short tons.[3]

TECHNOLOGY

Geology, mining and milling of graphite in the Malagasy Republic[4] and in Styria, Austria[5] were described.

In the Malagasy Republic flake graphite occurs in leptinites (granulites) and gneisses of the graphite system. Graphite-rich zones occupy an area south and west of Tamatave; a long region extending south from Tananarive; and an irregular patch near Ampanihy. Only the region near Tamatave is being exploited.

Graphite ore is mined from deposits in the lateritic overburden. Graphite beds may occupy several horizons separated by barren clay. Ore in the beds contains 5 to 10 percent graphite. Overburden is removed by bulldozers. Topography is rugged; advantage is taken of the high relief to dispose of overburden and to transport ore by water flowing in flumes to the washing plant.

At the washing plant, the ore pulp discharges from the flume over a screen with 5- to 10-millimeter openings. Oversize is discarded. Undersize is decanted to separate the mud, or slime, from the sand. Graphite in the mud overflow is recovered by hand screening on 50- to 80-mesh screens. Graphite from the screens is combined with the settled sand and treated in pneumatic flotation cells to recover the graphite. Pine oil and gas oil are used as reagents. The concentrate is trucked to a central concentrating plant where it is reground in a rod mill, refloated, dryed in wood- or oil-fired furnaces, screened and bagged.

Extensive government and private research programs were continued in the development of manufactured graphite articles for special uses. Graphite materials with density, permeability, and oxidation resistant characteristics previously unattainable were described to the American Society for Metals.[6]

In the investigation of methods of producing oxidation resistant graphite, research engineers at a U.S. Air Force laboratory vaporized a zirconium metal-organic compound (an alkoxide) that decomposed on contact with a heated graphite slab, leaving a continuous coating of zirconia resistant to temperatures up to 3,000° F.[7] Union Carbide Corp., Carbon Products Division announced development of a different type of graphite (JTA graphite).[8] A composite material consisting of graphite particles, binder, powdered zirconium diboride, and silicon is heated to approximately 4,100° F. and formed under pressures as high as 4,000 psi. The additives melt and fill the pores in the solid-phase graphite. As the graphite shape thus formed is heated to oxidation temperatures, the additives are oxidized and form a protective coating that prevents further oxidation.

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[3] Bureau of Mines. Mineral Trade Notes. V. 60, No. 2, February 1965, p. 19.

[4] Bureau of Mines. Mineral Trade Notes. V. 58, No. 4, April 1964, pp. 15–19.

[5] Klar, Gustav. Steirische (Styrian) Graphite. Die Universitäts-Buchdruckerei Styria, Graz, Austria, 1964, p. 149.

[6] Mining Journal (London). V. 262, No. 6707, Mar. 6, 1964, p. 182.

[7] Chemical Engineering. V. 71, No. 16, Aug. 3, 1964, p. 5.

[8] Chemical Engineering. V. 71, No. 10, May 11, 1964, p. 108.

A third method was patented[9] in which silicon metal is applied in limited quantities to a graphite surface, maintained at a temperature above the melting point of silicon, to form silicon carbide in the pores of the surface. Graphite then is removed from the surface layer by oxidation. Finally, molten silicon is applied to the porous surface; it forms a continuous coating that is bonded to the graphite by the intermediate layer of silicon carbide.

Production of carbon yarn by a continuous method was announced by Union Carbide Corp., Carbon Products Division.[10] Continuous production, compared to batch production, gives more uniform strength. Individual fiber strength has been raised to 180,000 psi. When heated, the fibers retain their strength up to 5,000° F. The fiber may be woven, knitted, braided or made into bonded fabrics.

In the production of carbon and graphite yarn, cloth, and felt,[11] special cellulosic fibers, spun into yarns and woven into fabrics, are carbonized under special conditions to drive off volatile matter and leave fibers of pure carbon, or graphite, depending on the temperature of carbonization.

The American Society for Testing and Materials, Committee C–5, organized a new subcommittee on Filaments, Fibers, and Fibrous Composites to collect all pertinent information on test methods for carbon and graphite yarns and fabrics.[12]

Research and development continued on pyrolytic graphite and carbon. Two patents[13] were issued covering methods of depositing carbon and graphite coatings on articles by thermal decomposition of a hydrocarbon gas in vacuum chambers. Three patents[14] were issued covering apparatus to be used for pyrolysis of hydrocarbons.

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[9] Kane, James S. (assigned to the United States of America as represented by the U.S. Atomic Energy Commission). Process for Producing Oxidation Resistant Refractory Coating on Dense Graphite. U.S. Pat. 3,140,193, July 7, 1964.

[10] Chemical Engineering. V. 71, No. 16, Aug. 17, 1964, p. 92.

[11] Cranch, G. E. Unique Properties of Flexible Carbon Fibers. American Carbon Committee, Proceedings of the Fifth Conference. Pergamon Press, New York, v. 1, 1962, pp. 589–594.

[12] Materials Research and Standards. V. 4, No. 4, April 1964, p. 182.

[13] Diefendorf, R. J. (assigned to General Electric Co.). Method for Depositing Carbon Coatings on High Temperature Material Members. U.S. Pat. 3,120,450, Feb. 4, 1964.

Diefendorf, R. J. (assigned to General Electric Co.). Deposition Method of Forming a Pyrolytic Graphite Article. U.S. Pat. 3,138,434, June 23, 1964.

[14] Diefendorf, R. J. (assigned to General Electric Co.), Deposition Apparatus and Method for Forming a Pyrolytic Graphite Article. U.S. Pat. 3,138,435, June 23, 1964.

Jacobs, J. K. (assigned to Hercules Powder Co.), Apparatus for Pyrolysis of Hydrocarbons. U.S. Pat. 3,154,385, Oct. 27, 1964.

Lefren, E. K. (assigned to Hercules Powder Co.), apparatus for Pyrolysis of Hydrocarbons. U.S. Pat. 3,154,386, Oct. 27, 1964.

Gypsum

By William R. Barton [1]

⁂

INCREASED demand for gypsum and gypsum products was noted in 1964 for the third consecutive year. Domestic production of crude gypsum increased 3 percent from 1963 while the quantity of imported crude increased 14 percent. Use of both calcined and uncalcined gypsum products increased.

TABLE 1.—Salient gypsum statistics

(Thousand short tons and thousand dollars)

	1955–59 (average)	1960	1961	1962	1963	1964
United States:						
Active mines and plants [1]	87	96	98	102	103	106
Crude: [2]						
Mined	10,139	9,825	9,500	9,969	10,388	10,684
Value	$33,927	$35,690	$34,996	$36,343	$38,138	$38,874
Imports for consumption	4,567	5,301	4,967	5,421	5,490	6,258
Calcined:						
Produced	8,529	8,591	8,246	8,819	9,181	9,440
Value	$93,302	$120,984	$118,145	$127,436	$131,668	$135,877
Products sold (value)	$331,895	$361,190	$358,811	$392,300	$414,090	$431,717
Gypsum and gypsum products:						
Imports for consumption (value)	$9,079	$10,426	$10,306	$11,912	$12,357	$14,687
Exports (value)	$1,534	$1,293	$1,299	$1,302	$1,431	$1,808
World: Production	40,000	44,100	45,310	48,740	49,900	51,530

[1] Each mine, calcining plant, or combination mine and plant is counted as 1 establishment.
[2] Excludes byproduct gypsum.

DOMESTIC PRODUCTION

Crude.—Of the 72 mines operated, 55 were open pit and 17 were underground. Eighty-one percent of the total output came from 39 mines operated by companies having calcining equipment. More than 90 percent of the crude gypsum mined in Texas, about 82 percent of that mined in Iowa, and 34 percent of that mined in Michigan was used in manufacturing calcined gypsum. More than 56 percent of the California output was sold uncalcined for agricultural purposes.

Calcined.—Domestic or imported gypsum was calcined at 72 plants. Gas was used for fuel at 48 plants, oil at 18 plants, and coal at 10 plants. A few of these plants used more than one type of fuel. A total of 9.3 billion square feet of board products reported in 1964 was made on 78 board machines.

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[1] Commodity specialist, Division of Minerals.

TABLE 2.—Crude gypsum mined in the United States, by States

(Thousand short tons and thousand dollars)

State	1963			1964		
	Active mines	Quantity	Value	Active mines	Quantity	Value
Arizona	(1)	(1)	(1)	6	147	$770
California	11	1,756	$4,222	9	1,893	4,539
Colorado	4	99	346	4	100	398
Iowa	5	1,282	5,667	5	1,287	5,821
Michigan	5	1,315	4,938	5	1,421	5,263
Nevada	3	890	3,216	3	799	2,894
New Mexico	3	179	656	(1)	(1)	(1)
New York	5	647	3,339	5	653	3,321
Oklahoma	7	531	1,462	8	694	1,899
South Dakota	1	24	97	1	19	76
Texas	7	1,099	3,999	7	1,131	4,049
Other States [2]	20	2,566	10,196	19	2,540	9,844
Total	71	10,388	38,138	72	10,684	38,874

[1] Included with "Other States."

[2] Includes the following States to avoid disclosing individual company confidential data: Louisiana and Virginia, 1 mine each; Arkansas, Indiana, Kansas, Montana, Ohio, Utah, and Wyoming, 2 mines each; New Mexico (1964), 3 mines; and Arizona (1963), 4 mines.

TABLE 3.—Calcined gypsum produced in the United States, by States

(Thousand short tons and thousand dollars)

State	1963					1964				
	Active	Quantity	Value	Calcining equipment		Active plants	Quantity	Value	Calcining equipment	
				Kettles	Other [1]				Kettles	Other [1]
California	6	1,017	$9,936	18	13	7	1,019	$9,662	19	14
Colorado	(2)	(2)	(2)	(2)	(2)	2	41	383	2	3
Iowa	5	896	13,423	23	4	5	883	13,467	23	4
Louisiana	3	227	4,035	6	1	3	218	3,897	6	1
Michigan	4	372	5,360	14	1	4	403	6,300	11	1
New York	7	1,192	18,269	24	6	7	1,100	16,669	24	5
Ohio	3	324	4,913	9	1	(2)	(2)	(2)	(2)	(2)
Texas	6	822	12,075	29	--------	7	913	12,886	29	3
Other States [3]	34	4,331	63,657	101	36	37	4,863	72,613	118	41
Total	68	9,181	131,668	224	62	72	9,440	135,877	232	72

[1] Includes rotary and beehive kilns, grinding-calcining units, Holo-Flites, and Hydrocal cylinders.

[2] Figure withheld to avoid disclosing individual company confidential data; included with "Other States."

[3] Comprises States and number of plants as follows: Arizona, 1; Arkansas (1964) 1; Colorado (1963), 2; Connecticut, 1; Delaware, 1; Florida, 2; Georgia, 2; Illinois, 1; Indiana, 3; Kansas, 2; Maryland, 2; Massachusetts, 1; Montana, 1; Nevada, 2; New Hampshire, 1; New Jersey, 2; New Mexico, 2; Ohio (1964), 3; Oklahoma (1963), 1, (1964) 2; Pennsylvania, 1; Utah, 2; Virginia, 2; Washington, 1; and Wyoming, 1.

Mine and Products-Plant Development.—The new Dierks-Forest Inc., wallboard plant at Nashville, Ark., was fully operable. Fiberboard Paper Products Corp. announced it would open a gypsum wallboard plant at Apex, Nev., in 1965. The plant will utilize local gypsum at the Flintkote Co., board plant at Savannah, Ga., which was to be fully operable in early 1965; board and other gypsum products will be made from Newfoundland ore. The Flintkote Co. plant under construction at Fremont, Calif., also was scheduled to start in 1965. The company plant at Camden, N.J., opened in 1963, was described.[2] The Gypsum Products of America Corp. announced that its proposed plant at Lovell, Wyo., will cost $3 million. The plant will employ 138 persons. The Area Redevelopment Administration and the Small Business Administration approved a $2 million loan to help finance the project. The Harquahala Gypsum Co., opened an agricultural gypsum mine and mill 15 miles southwest of Salome, Ariz. Daily production capacity was 100 tons of ground gypsum. A new Kaiser Cement and Gypsum Co., Inc., plant at Jacksonville, Fla., commenced operation in the fall of 1964. Kaiser planned to open another wallboard and plaster plant at Delanco, N.J., in late 1965 having the same annual capacity as the Jacksonville plant: 180 million square feet of board products and 40,000 tons of plaster. Approximately 100 persons will be employed. National Gypsum Co., opened a plant at Richmond, Calif. utilizing rock gypsum from Mexico. It also began construction of a $7.5 million plant at Long Beach, Calif., and announced plans to build additional production facilities at Tacoma, Wash., and in "the Great Lakes area." The wallboard plant of Republic Gypsum Co. at Duke, Okla., opened late in 1964. United States Gypsum Co. began construction of a $4 million board plant at Santa Fe Springs, Calif., to open in 1965. Vipont Mining Co. completed drilling for gypsum on the Wind River Indian Reservation, Wyo. It is seeking $50 million in Federal loans to assist construction of a mill at Shoshoni, Wyo. of board plants at Seattle, Wash., and St. Louis, Mo., and of a railroad from the deposit at Bargee to Shoshoni.

CONSUMPTION AND USES

Total housing and apartment starts, a guide to demand for gypsum products, declined slightly in 1964. However, while the number of private nonfarm housing starts was only 1.52 million units compared with 1.58 million units in 1963, the value of new nonfarm residential building increased from $20,100 million to $20,600 million. This was due to bigger, more expensive units. From 1954 to 1964 the average size of new single family homes increased from 1,100 square feet to 1,300 square feet, with concomitant increase usage of gypsum products per unit. The total value of new construction put in place in the United States was $66,000 million in 1964, compared with $62,500 million in 1963. Apartment-house and multi-unit dwelling construction continued to flourish, comprising 38 percent of total housing starts in 1964 compared with about 20 percent 5 years earlier.

The share of the gypsum market for building purposes continued to be dominated by prefabricated products. Until after World War I, the market for board and related items was less than 10 percent of the market for building plasters. Plasters remained higher in tonnage used than board products until World War II. Board products expanded their share of the gypsum building market from 57 percent in 1946 to 81 percent in 1964. The amount of building plaster sold reached a peak in 1955; however, the amount of building plaster sold in 1964 was about the same as in 1946, but in the same 18 years demand for prefabricated gypsum building products has more than tripled.

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[2] Bergstrom, J. H. Process Innovations Highlight Gypsum Plant. Rock Products, v. 67, No. 8, August 1964, pp. 58–60.
Herod, B. C. Flintrock Production Expanded With New Eastern Operation. Pit and Quarry, v. 57, No. 2, August 1964, pp. 76–81.

TABLE 4.—Gypsum products (made from domestic, imported and byproduct gypsum) sold or used in the United States, by uses

(Thousand short tons and thousand dollars)

Use	1963		1964	
	Quantity	Value	Quantity	Value
Uncalcined:				
Portland-cement retarder	2,898	$12,931	3,034	$12,997
Agricultural gypsum	1,262	4,372	1,475	5,518
Other uses [1]	49	562	53	623
Total	4,209	17,865	4,562	19,138
Calcined:				
Industrial:				
Plate-glass and terra-cotta plasters	46	776	50	788
Pottery plasters	50	1,115	53	1,218
Dental and orthopedic plasters	13	484	14	541
Industrial molding, art, and casting plasters	90	1,945	99	2,165
Other industrial uses [2]	80	2,774	76	2,796
Total	279	7,094	292	7,508
Building:				
Plasters:				
Base-coat	1,036	19,158	972	18,667
Sanded and premixed perlite	477	11,837	455	11,515
To mixing plants	1	21	(3)	3
Gaging and molding	123	2,649	121	2,703
Prepared finishes	9	821	9	817
Roof-deck	325	4,622	352	5,438
Other [4]	19	1,033	22	1,108
Keene's cement	36	963	34	936
Total	2,026	41,104	1,965	41,187
Prefabricated products [5]	[6] 8,214	348,027	[6] 8,642	363,884
Total	------------	389,131	------------	405,071
Grand total, value	------------	414,090	------------	431,717

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[1] Includes uncalcined gypsum for use as filler and rock dust, in brewer's fixe, in color manufacture, and for unspecified uses.

[2] Includes dead-burned filler, granite polishing, and miscellaneous uses.

[3] Less than ½ unit.

[4] Includes joint filler, patching, painter's, insulating, and unclassified building plasters.

[5] Excludes tile.

[6] Includes weight of paper, metal, or other materials.

TABLE 5.—Prefabricated products sold or used in the United States, by products

Product	1963			1964		
	Thousand square feet	Thousand short tons [1]	Value (thousands)	Thousand square feet	Thousand short tons [1]	Value (thousands)
Lath:						
⅜-inch	1,486,624	1,113	$40,490	1,393,022	1,038	$38,744
½-inch	58,533	59	2,087	95,581	96	3,513
Other [2]	3,903	7	182	6,008	8	306
Total	1,549,060	1,179	42,759	1,494,611	1,142	42,563
Wallboard:						
¼-inch	134,585	76	4,296	133,077	76	4,073
⅜-inch	1,881,293	1,432	67,796	1,767,135	1,341	63,811
½-inch	4,547,745	4,566	192,386	4,988,816	4,983	206,783
⅝-inch	534,178	678	30,687	639,618	806	36,454
1-inch [3]	11,326	24	1,024	13,564	29	1,086
Total	7,109,127	6,776	296,189	7,542,210	7,235	312,207
Sheathing	196,935	206	6,970	197,453	208	6,790
Laminated board	[4] 6,568	6	333	6,691	6	323
Formboard	44,582	47	1,776	48,462	51	2,001
Grand total [5]	8,906,272	8,214	348,027	9,289,427	8,642	363,884

[1] Includes weight of paper, metal, or other materials.
[2] Includes a small amount of ¼-inch, ⅝-inch, and 1-inch lath.
[3] Includes a small amount of 5/16-inch, ¾-inch, 1 ⅝-inch, and 3 ¾-inch wallboard.
[4] Area of component board and not of finished product.
[5] Excludes tile, for which figures are withheld to avoid disclosing individual company confidential data

STOCKS

Producer stocks of crude gypsum on hand December 31 totaled 4.16 million tons, a 6 percent increase from the 3.94 million tons reported at the end of 1963.

PRICES

Prices (base rates) for truckload lots of gypsum products in 20 U.S. cities are published monthly in Engineering News-Record. Neat plaster averaged $31.54 per ton and ranged from $24 in Baltimore to $45.50 in Seattle. Gauging plaster sold for an average of $36.92 per ton and ranged from $25.65 at Cincinnati to $48 at Seattle. One-half inch gypsum board averaged $63.06 per thousand square feet and ranged from $49 at Cincinnati to $75.50 at Seattle. Quotations for ¾-inch board averaged $53.65 and ranged from $43.85 at Cincinnati to $64.50 at Seattle. Three-eighths-inch gypsum lath averaged $43 and ranged from $33.05 in the Cincinnati market to $56.75 at Seattle. Tongue and groove sheathing averaged $59.18 and ranged from $43 in the Cincinnati area to $74 at St. Louis.

FOREIGN TRADE

Imports of crude gypsum increased 14 percent compared with 1963. Canada provided 78 percent of the total crude imports; Mexico 17 percent; and Jamaica 2 percent.

TABLE 6.—U.S. imports for consumption of gypsum and gypsum products[1]

Year	Crude (including anhydrite)		Ground or calcined		Alabaster manufactures,[2] value (thousands)	Other manufactures n.e.s., value (thousands)	Total value (thousands)
	Short tons	Value (thousands)	Short tons	Value (thousands)			
1955-59 (average)	4,567,266	$8,082	953	$37	$579	$381	$9,079
1960	5,301,224	8,990	1,159	48	963	425	10,426
1961	4,967,061	9,043	1,127	51	836	376	10,306
1962	5,420,876	10,490	1,780	55	1,025	342	11,912
1963	5,490,298	10,887	226	62	1,031	377	12,357
1964	6,257,702	13,305	1,364	53	945	384	14,687

[1] In addition, Keene's cement was imported as follows; 1955-59 (average) none; 1960-61, none; 1962, 2,760 short tons ($2,073), 1963-64 none.

[2] Includes imports of jet manufactures, which are believed to be negligible.

Source: Bureau of the Census.

TABLE 7.—U.S. imports for consumption of crude gypsum (including anhydrite), by countries

(Thousand short tons and thousand dollars)

Country	1963		1964	
	Quantity	Value	Quantity	Value
North America:				
Canada	4,400	$8,714	4,891	$10,187
Dominican Republic	26	77	111	360
Jamaica	169	508	156	584
Mexico	891	1,577	1,074	2,125
Total	5,486	10,876	6,232	13,256
South America: Colombia	-----	-----	18	28
Europe	4	11	(1)	(1)
Oceania: Australia	-----	-----	8	21
Grand total	5,490	10,887	6,258	13,305

(1) Less than ½ unit.

Source: Bureau of the Census.

TABLE 8.—U.S. exports of gypsum and gypsum products

Year	Crude, crushed, or calcined		Other manufactures n.e.c., value (thousands)	Total (thousands)
	Short tons (thousands)	Value (thousands)		
1955-59[1] (average)	22	$755	$779	$1,534
1960	17	687	606	1,293
1961	20	731	568	1,299
1962	20	736	566	1,302
1963	17	669	762	1,431
1964	21	829	979	1,808

[1] Effective Jan. 1, 1958, plasterboard, wallboard, and tile not separately classified included with "gypsum manufactures, n.e.c." 1955: 8,686,854 square feet, $412,397; 1956: 7,026,932 square feet, $363,648; 1957: 8,866,572 square feet, $519,668.

Source: Bureau of the Census.

WORLD REVIEW

NORTH AMERICA

Canada.—Gypsum production increased 7 percent in 1964 as a result of greater demand from the United States. Locations of gypsum mines in Canada were published on a map.[3] Operating companies were: Atlantic Gypsum Ltd., Flat River, Newfoundland; The Flintkote Company of Canada Ltd., Flat Bay, Newfoundland; The Bestwall Gypsum Co. (Canada) Ltd., River Denys, Nova Scotia; Domtar Construction Materials Ltd., Nappan and Newport, Nova Scotia, Caledonia, Ont., and Gypsumville, Manitoba; Fundy Gypsum Co., Ltd., Miller's Creek and Wentworth, Nova Scotia; Little Narrows Gypsum Co., Ltd., Little Narrows, Nova Scotia; National Gypsum (Canada) Ltd., Walton, Cheverie, and Milford Station, Nova Scotia; Canada Cement Co., Ltd., Havelock, New Brunswick; Canadian Gypsum Co., Ltd., Hillsborough, New Brunswick and Hagersville, Ontario; Western Gypsum Products, Ltd., Amaranth, Manitoba, and Windemere Creek, British Columbia.

Mexico.—A deposit containing 2,400 millions tons of gypsum is located at LaBorrega. A method was being developed for producing sulfurous gases from the raw material mixed with coal.[4]

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[3] Canada Department of Mines and Technical Surveys. Principal Mineral Areas of Canada. Map 900A, 14th ed., 1964, 1 p.

[4] Chemical Trade Journal and Chemical Engineer (London). Mexico-Rise in Sulphur Consumption. V. 155, No. 4041, Nov. 20, 1964, p. 713.

TABLE 9.—World production of gypsum by countries [1] [2]

(Thousand short tons)

Country [1]	1960	1961	1962	1963	1964 [p]
North America:					
Canada [3]	5,093	5,060	5,155	5,955	6,374
Dominican Republic	358	451	484	39	[e] 33
Jamaica	275	250	252	256	174
Mexico	871	857	876	1,210	[e] 1,323
United States	9,825	9,500	9,969	10,388	10,684
Other countries: Cuba, Guatemala, Nicaragua, and Trinidad	52	38	40	49	29
Total [e]	16,474	16,156	16,776	17,897	18,617
South America:					
Argentina	160	198	237	156	[e] 149
Brazil	114	172	119	132	[e] 132
Chile	45	88	127	116	143
Colombia	77	83	91	112	[e] 121
Other countries: Peru and Venezuela	133	136	136	129	144
Total [e]	529	677	710	645	689
Europe:					
Austria [3]	730	750	754	644	626
Bulgaria	132	149	129	110	[e] 121
Czechoslovakia	364	390	411	333	387
France [3]	4,163	4,227	4,406	4,639	[4] 4,639
Germany:					
East [5]	276	284	302	284	[4] 284
West (marketable)	1,153	1,315	1,227	1,168	[e] 1,273
Greece	94	99	104	[e] 105	[e] 105
Ireland	200	184	194	219	251
Italy	2,098	2,293	3,496	2,285	[4] 2,285
Poland	[2] 573	516	605	645	[4] 645
Spain	2,296	2,822	3,287	4,258	[4] 4,258
Switzerland	[e] 110	[e] 110	[e] 110	[e] 110	[e] 110
U.S.S.R	5,095	4,912	4,824	4,673	[e] 4,740
United Kingdom [3]	4,026	4,179	4,479	4,567	5,052
Yugoslavia	137	107	[e] 110	156	170
Other countries: Luxembourg and Portugal	77	87	89	73	71
Total [e]	21,610	22,510	24,640	24,380	25,130
Asia:					
China [e]	650	450	450	550	650
Cyprus	124	115	115	[e] 110	[e] 110
India	1,099	953	1,239	1,309	970
Iran [e] [6]	440	1,100	1,100	1,100	1,300
Iraq [e]	440	550	550	550	550
Israel [e] [7]	65	90	80	115	120
Japan	810	799	882	863	830
Pakistan	100	112	201	218	215
Turkey	67	[e] 65	154	198	[e] 220
Other countries: Burma, Jordan, Mongolia, Philippines, Saudi Arabia, Syrian Arab Republic, Taiwan, and Thailand	64	63	108	171	181
Total [e]	3,859	4,297	4,879	5,184	5,146
Africa:					
Algeria	195	[e] 195	[e] 195	[e] 195	[e] 195
South Africa, Republic of	216	191	212	207	265
United Arab Republic (Egypt)	441	510	515	[e] 518	[e] 518
Other countries: Angola, Ethiopia, Kenya, Morocco, Sudan, Tanzania, and Tunisia	81	89	104	99	112
Total [e]	933	985	1,026	1,019	1,090
Oceania: Australia	651	683	707	770	[e] 860
World total (estimate) [1] [2]	44,100	45,310	48,740	49,900	51,530

[e] Estimate. [p] Preliminary.

[1] Gysum is also produced in Rumania, but production data are not available; an estimate is included in the total. Production in Ecuador and Korea is negligible.

[2] This table incorporates some revisions. Data do not add exactly to totals shown because of rounding where estimated figures are included in the detail.

[3] Includes anhydrite.

[4] 1963 data.

[5] Crude production estimates based on calcined figures.

[6] Year ended March 20 of year following that stated.

[7] Year ended March 31 of year following that stated.

SOUTH AMERICA

Chile.—About half the gypsum produced in Chile was calcined for use as a building material. Most of the remainder was sold to the cement industry.

Peru.—About 55 percent of the gypsum produced by four Peruvian companies was calcined. The remainder was utilized as a cement additive.

EUROPE

Poland.—Gypsum planning including 1965 industry targets were described in a translation made available in 1964.[5]

ASIA

India.—A 1.7 million ton deposit of gypsum, variety selenite, was found in the Barmer district of Rajasthan in the form of a narrow vein.

Thailand.—A new gypsum products plant of Thai Gypsum Company consumes about 16 tons of rock gypsum daily at optimum operating level.[6]

TECHNOLOGY

Because raw material resources are abundant and production methods essentially standardized, relatively little research effort was devoted to those sectors of technical investigation. Most work was on improving product characteristics and methods of use. The most significant developments in these fields were thin-coat plaster, predecorated wallboard, screw lath and wallboard application, and improved sound deadening techniques.

An old gypsum mine at Clarence, N.Y., has been selected for use as a bomb shelter in case of nuclear attack. When fully converted it will have a capacity of 34,000 persons. An 11-foot-thick gypsum bed was discovered near LaPorte by the Indiana Geological Survey.

A Japanese process successfully purified phosphogypsum for use as a portland cement regulator.[7] The process consists essentially of preheating the gypsum to 575° F and then neutralizing and washing it with a solution of lime and other compounds. A U.S. patent was issued on the process.[8]

The flowsheet and chemistry of two processes resulting in phosphogypsum residues were described.[9]

A process and apparatus for sequential progressive calcination of rock gypsum to produce gypsum hemihydrate was patented.[10] Improved plaster compositions were also announced.[11] In various new compositions, methyl cellulose or copolymers of alkyl acrylate monomers with acrylic acid or acrylonitrite were incorporated.

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[5] Twardosz, Tadensz. Prospects for Lime and Gypsum Industries During the Five-Year Plan. U.S. Dept. of Commerce, Office of Tech. Services, OTS 63-11389, 1964, 6 pp. (translated from Cement-Wapno-Gips, No. 5, 1960, pp. 121–123).

[6] Bureau of Mines. Mineral Trade Notes. V. 58, No. 3, March 1964, p. 14.

[7] Rock Products, Mining, and Processing. V. 67, No. 3, March 1964, p. 12.

[8] Yamaguchi, Taro (assigned to Onoda Cement Co. Ltd., Onoda, Japan). Method of Improving the Grade of Byproduct Gypsum Obtained in Carrying Out a Wet Process for Production of Phosphoric Acid. U.S. Pat. 3,159,497, Dec. 1, 1964.

[9] Chemical Engineering. Concentrated Phosphoric Acid Again in Limelight. V. 71, No. 26, Dec. 21, 1964, pp. 34–36.

[10] Stevens, N. J. (assigned to Jay Manufacturing Co., Pittsburgh, Pa.). Semi-Continuous Material Treatment Process. U.S. Pat. 3,158,441, Nov. 24, 1964.

The use of gypsum to regulate pH during smelting of low-grade cupriferous iron ore was patented.[12]

The use of gypsum plaster for leveling up and holding plate glass during grinding and polishing has been affected by a technological change in plate glass production. The new "float glass" process involves the cooling of molten glass on a bed of molten metal, which produces a smooth surface finish without polishing and thus eliminates the need for gypsum.

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[11] Sherr, A. E. (assigned to American Cyanamid Co., New York). Calcium Sulfate Plasters Containing Alkyl Acrylate Copolymers. U.S. Pat. 3,121,702, Feb. 18, 1964.

Tallentire, A. G., and C. Green (assigned to Imperial Chemical Industries, Ltd., London). Plaster Compositions. U.S. Pat. 3,153,596, Oct. 20, 1964.

[12] Udy, M. C. (assigned to Independence Foundation, Philadelphia, Pa., and Koppers Company, Inc., Pittsburgh, Pa.). Metallurgical Process. U.S. Pat. 3,155,492, Nov. 3, 1964.

Iodine

By William C. Miller[1]

◆

PRODUCTION and value of crude iodine extracted from natural brines of Michigan and oil well brines of California increased slighty over output and value in 1963. Michigan replaced California as the prime domestic iodine source.

Imports of crude iodine decreased in 1964, reversing the upward trend of the previous 4 years.

Prices remained firm for iodine and its compounds except for an increase for potassium iodides.

The Office of Emergency Planning announced that the stockpile objective was increased from 4.3 million pounds to 8 million pounds.

DOMESTIC PRODUCTION

Crude iodine production increased 14 percent in quantity and 13 percent in value, compared with that of 1963. Iodine was extracted from waste oil well brines at Seal Beach, Calif., and from natural brines at Midland, Mich., by The Dow Chemical Co. Over half of the total production of crude iodine was obtained from the natural brines of Michigan.

CONSUMPTION AND USES

For the 2d consecutive year a record high was established in the U.S. consumption of crude iodine. Consumption of resublimed iodine and iodine compounds increased 16 percent over the high established in 1963. A 26-percent increase in the consumption of potassium iodide, the principal iodine compound, reversed the downward trend in its consumption of the last 2 years. Consumption of resublimed iodine increased 7 percent, inorganic compounds, excluding potassium iodide, 4 percent, and organic compounds 19 percent, compared with that of 1963.

During 1963 many applications were found in medicine, agriculture, sanitation, and industry for the utilization of iodine and its compounds. Resumblimed iodine was used for its medicinal properties, preparation of organic and inorganic compounds, in the manufacture of dyes and intermediates, and as an analytical reagent. Potassium

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[1] Commodity specialist, Division of Minerals.

TABLE 1.—Crude iodine consumed in the United States

Product	1963			1964		
	Number of plants	Crude iodine consumed		Number of plants	Crude iodine consumed	
		Thousand pounds	Percent of total		Thousand pounds	Percent of total
Resublimed iodine	7	150	5	8	160	5
Potassium iodide	11	1,018	38	12	1,285	41
Sodium iodide	4	(1)	(1)	4	(1)	(1)
Other inorganic compounds	21	910	34	18	946	30
Organic compounds	24	617	23	25	737	24
Total	[2] 43	2,695	100	[2] 43	3,128	100

[1] Included with "Other inorganic compounds" to avoid disclosing individual company confidential data.
[2] Nonadditive total because some plants produce more than 1 product.

iodide was consumed in germicides and antiseptics, in aniline, phthalein and other dyes, as a catalyst for intermediates manufacture, as an analytical and process reagent, as a pharmaceutical chemical, and in the preparation of animal feed, mineral mixes, and iodized salt. Sodium and ammonium iodides were used for similar purposes. Titanium tetraiodide was used as a catalyst. The usage of calcium iodide in animal feeds was greatly increased. Organic compounds were used as pigments and dyes, in detergents and sanitizers, as a bactericide, sporocide and fungicide, for organic synthesis, and in medicines.

A new development was in the addition of a trace of iodine in mercury lamps and to the filaments of automobile headlights which prolongs the life of the lamps.

STOCKS

Stocks held by firms that convert crude iodine into resublimed iodine and iodine compounds totaled 1,112,517 pounds on December 31, 1964.

Action by the Office of Emergency Planning on March 5, 1964, established a revised stockpile objective for iodine of 8 million pounds. Government inventories of iodine on December 31, 1964, totaled 4,290,276 pounds, of which 2,956,713 pounds was in the strategic stockpile and 1,333,563 pounds was in the supplemental stockpile.

PRICES

The price of iodine and its compounds, except potassium iodide, remained constant during 1964. An increase in the price ranged from 12 to 22 cents per pound for large quantities of potassium iodide and from 9 to 19 cents per pound for small quantities. Feed grade mixture remained firm at $1.25 to $1.35 per pound for 500-pound lots. The following prices were quoted for iodine and iodine compounds by the Oil, Paint and Drug Reporter:

	Per pound
Crude iodine, kegs	$1.18
Resublimed iodine, U.S.P., drums, f.o.b. works	2.20–2.22
Amonium iodide, National Formulary (N.F.), 25-pound jars, f.o.b. works	4.51
Calcium iodide, 25-pound jars, f.o.b. works	4.27
Potassium iodide, U.S.P., crystals, drums, 500-pounds or more, delivered:	
Jan. 1 to May 11	1.23
May 11 to June 1	1.23–1.35
June 1 to June 15	1.23–1.45
June 15 to Dec. 31	1.35–1.45
Potassium iodide, U.S.P., crystals, drums, smaller lots, delivered:	
Jan. 1 to May 11	1.28
May 11 to June 1	1.28–1.37
June 1 to June 15	1.28–1.47
June 15 to Dec. 31	1.37–1.47
Sodium iodide, U.S.P., 300-pound drums, f.o.b. works	2.13

FOREIGN TRADE

Crude iodine imports for consumption decreased in 1964, reversing the upward trend of the past 4 years. The quantity declined 22 percent and the value 20 percent, compared with that of 1963. Imports from Chile, the major source, were 29 percent less than the shipments received in 1963. Resublimed iodine imports from Japan totaled 3,000 pounds valued at $4,266, the same quantity as in 1963 but an increase of 12 percent in value.

Exports were made to 44 countries or 9 more than in 1963. The five countries receiving the largest shipments were the United Kingdom, Mexico, Canada, Netherlands, and India and accounted for 56 percent of the total quantity.

TABLE 2.—U.S. imports for consumption of crude iodine, by countries

(Thousand pounds and thousand dollars)

Country	1955–59 (average)		1960		1961	
	Quantity	Value	Quantity	Value	Quantity	Value
Canada	----	----	----	----	----	----
Chile	1,333	$1,276	1,420	$1,011	1,964	$1,822
Japan	397	498	474	414	1,053	1,030
Total	1,730	1,774	1,894	1,425	3,017	2,852

Country	1962		1963		1964	
	Quantity	Value	Quantity	Value	Quantity	Value
Canada	----	----	----	----	29	$31
Chile	2,229	$2,054	2,462	$2,093	1,759	1,492
Japan	797	787	874	865	804	846
Total	3,026	2,841	3,336	2,958	2,592	2,369

Source: Bureau of the Census.

TABLE 3.—U.S. exports of iodine, iodide, and iodates

(Thousand pounds and thousand dollars)

Year	Quantity	Value	Year	Quantity	Value
1955-59 (average)	271	$401	1962	178	$296
1960	251	353	1963	141	327
1961	176	282	1964	147	343

Source: Bureau of the Census.

TABLE 4.—U.S. reexports of iodine, iodide, and iodates

(Thousand pounds and thousand dollars)

Year	Quantity	Value	Year	Quantity	Value
1955-59 (average)	54	$67	1962	64	$71
1960	38	37	1963	47	52
1961	85	94	1964	8	9

Source: Bureau of the Census.

Both the quantity and value of reexports of iodine, iodide, and iodates declined by 83 percent. Shipments of crude iodine by foreign producers were made directly to consumers rather than to warehouses in New York where the iodine was stored until reexported as needed. The number of countries to which shipments were made was reduced from five to three.

WORLD REVIEW

Chile.—Production of crude iodine in calendar year 1963 amounted to 4,753,000 pounds which was 8 percent less than that produced in 1962. Anglo-Lautro Nitrate Corp. produced 4,392,000 pounds, or more than 92 percent of the total output. Exports reported by the Chilean Nitrate Sales Corp. was 3,990,000 pounds, a 23 percent decrease from 1962. United States received 54 percent of the exports, European countries 45 percent, and South American countries 1 percent.[2]

Japan.—Elemental iodine recovery in 1964 increased to 4,464,000 pounds, compared with 3,118,000 pounds in 1963.

TECHNOLOGY

To provide accurate data for use in chemical and metallurgical process calculations, the determination of certain thermodynamic properties of sodium iodide were made. Results of low-temperature heat-capacity measurements and calculations of thermodynamic functions were reported.[3]

A comparative study was made of the predominant microbial flora of iodinated and chlorinated swimming pool waters. In the swimming pools tested, results showed that iodine was an efficient microbicide. As iodine concentrations were easily maintained and were relatively more stable than chlorine concentrations, iodine appeared to be more effective.[4]

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[2] Bureau of Mines. Mineral Trade Notes. V. 59, No. 2, August 1964, p. 31.

[3] Gardner, T. Estelle, and A. R. Taylor, Jr. Thermodynamic Properties of Sodium Bromide and Sodium Iodide at Low Temperatures. BuMines Rept. of Inv. 6435, 1964, 8 pp.

A free iodine residual of 0.2 parts per million was found to be an effective control for bacteria, algae, and protozoa in swimming pool water. Tests were made using free iodine, iodine plus potassium iodide, and free chlorine to determine the amount necessary for control.[5]

Two methods of preparing pure iodine oxide pentafluoride from iodine heptafluoride have been reported. One method employs the reaction of the heptafluoride with water and the other with iodine pentoxide.[6]

Results of electrochemical experiments indicated the presence of absorbed iodine and absence of absorbed iodide on platinum electrodes. Iodine and iodide were absorbed in the experiments, but only the absorbed iodine was proven electroactive by radiotracer experiments.[7]

The formation of radioactive methyl iodide by the recoil of fission-produced iodine isotopes was studied. Higher efficiency of the recoil labeling of methyl iodide by fission-produced isotopes was found with independently produced iodine than with the same isotopes recoiling after β-decay.[8]

A completely automatic technique using a continuous digestor and standard Autoanalyser units has been developed for determinations of serum protein-bound iodine and total iodine.[9]

Measurements were made with commercially available dectors and spectrometers to determine the absolute activity of the medical radioisotope, I^{125}. The surfaces of the crystals required polishing to prevent spurious spectral distortions which gave erroneous results.[10]

Experiments using alpha-silver iodide as the electrolyte in silver and iodine thermogalvanic cells were described. Results of the experiments indicated that the silver cell has the more promise of practical applications.[11]

Results from an analysis of the elastic strain distribution in cold-worked hexagonal silver iodide were reported.[12]

A new process was developed for preparing high yields of unusually pure organic iodides. The process was based on the direct interaction of elementary iodine with alcohol or ether in the presence of a small quantity of diborane or other boron hydrides.[13]

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[4] Favero, Martin S., and Charles H. Drake. Comparative Study of Microbial Flora of Iodinated and Chlorinated Pools. Public Health Reports (Public Health Service, U.S. Department of Health, Education, and Welfare), v. 79, No. 3, March 1964, pp. 251–257.

[5] Lackey, J. B., E. W. Lackey, and G. B. Morgan. Iodine as an Algaecide for Swimming Pools. Eng. Progress at the Univ. of Florida, v. 18, No. 3, March 1964, 8 pp.

[6] Chemistry. Iodine Oxide Pentafluoride. V. 37, No. 4, April 1964, pp. 21, 22.

[7] Osteryoung, R. A., and F. C. Anson. Behavior of the Iodide-Iodine Couple at Platinum Electrodes. Anal. Chem., v. 36, No. 6, May 1964, pp. 975–980.

[8] Paiss, Yehuda, and Saadia Amiel. Selectivity Effects in Recoil Labeling of Methyl Iodine by Fission-Produced Iodine. Chem. Soc. J., v. 86, No. 12, June 20, 1964, p. 2332.

[9] Chemical Age (London). Iodine Determinations. V. 91, No. 2346, June 27, 1964, p. 1028.

[10] Eldridge, James S., and Peter Crowther. Absolute Determination of I^{125} in Clinical Applications. Nucleonics, v. 22, No. 6, June 1964, pp. 56–59.

[11] Weininger, J. L. Thermogalvanic Cells with Silver Iodide as a Solid Electrolyte. J. Electrochem. Soc., v. 111, No. 7, July 1964, pp. 769–774.

[12] Burley, G. X-Ray Investigation of Strain in Cold-Worked Silver Iodide. NBS J. Res. v. 68A (Physics and Chemistry), No. 4, July–August 1964, pp. 355–358.

[13] Freeguard, G. F., and L. H. Long. A Novel Method for Preparing Organic Iodides. Chem. and Ind. (London), No. 37, Sept. 12, 1964, pp. 1582, 1583.

A radioiodine effluent monitor for collecting volatile, particulate and compound forms of Iodine-131 was placed on the market. The efficiency of the unit is greater than 98 percent.[14]

A kinetic experiment was conducted to study the rate of oxidation of iodide ion by persulfate ion. The effect of temperature, influence of ionic strength, and effect of a catalyst on the rate of chemical reaction was investigated.[15]

A germicidal agent of iodine and liquid lanolin was developed. The reaction product of iodine and lanolin contained from 1/4 percent to 25 percent iodine by weight.[16]

A process was patented for the preparation of hydrogen iodide by the reaction of hydrogen and iodine at an elevated temperature and in the presence of a catalytic composite.[17]

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[14] Chemical Week. Radioiodine Effluent Monitor. V. 95, No. 11, Sept. 12, 1964, pp. 153–154.

[15] Moews, P. C., Jr., and P. H. Petrucci. The Oxidation of Iodide Ion by Persulfate Ion. J. Chem. Education, v. 41, No. 10, October 1964, pp. 549–551.

[16] Perlman, Samuel Donald. Germicidal Composition of Iodine and Liquid Lanolin. U.S. Pat. 3,152,951, Oct. 31, 1964.

[17] Gerald, Curtis F. (assigned to El Paso Natural Gas Products Co., El Paso, Tex.). Process for Catalytically Reacting Hydrogen and Iodine to Produce Hydrogen Iodine. U.S. Pat. 3,154,382, Oct. 27, 1964.

Iron Ore

By Horace T. Reno[1]

❖

IRON mining companies announced that they would build taconite processing plants on the Mesabi Range with a total capacity to produce 10 million tons of high-grade pellets annually. The action immediately followed the approval of an amendment to the Minnesota State's constitution which provides that for the next 25 years, taxes assessed against taconite mining companies will not be increased above the general corporate level. The State of Michigan revised its tax laws to permit underground mines to qualify for tax relief applicable to low-grade pelletized ores from open-pit mines. Soon afterwards it was announced, that a pelletizing plant to treat ores from underground mines in the Marquette range with a rated capacity of 2 million tons of pellets per year would be built. The Cleveland-Cliffs Iron Co. hired its first new employee in 7 years to work in the mines. Thus, the iron mining industry of the Lake Superior region planned to reverse a 10-year downward trend as projected gains in taconite and jaspilite mining more than offset anticipated losses in mining conventional iron ores.

TABLE 1.—Salient iron ore statistics

(Thousand long tons and thousand dollars)

	1955–59 (Average)	1960	1961	1962	1963	1964
United States:						
Iron ore (usable;[1] less than 5 percent Mn):						
Production[2]	87,003	88,784	71,329	71,829	73,599	84,836
Shipment[3]	86,359	82,963	72,379	69,969	73,564	84,300
Value[3]	$689,581	$724,131	$650,500	$618,242	$678,181	$802,331
Average value at mines per ton	$7.99	$8.73	$8.99	$8.84	$9.22	$9.52
Imports for consumption	30,139	34,578	25,805	33,409	33,263	42,408
Value	$251,412	$321,919	$250,226	$324,573	$323,158	$421,288
Exports	4,313	5,273	4,958	5,898	[r] 6,812	6,963
Value	$40,413	$57,899	$54,230	$62,847	[r] $76,340	$79,670
Consumption	113,027	108,050	99,254	99,562	112,535	132,328
Stocks Dec. 31:						
At mines[2]	6,183	12,337	10,335	11,614	[r] 11,099	[r] 10,752
At consuming plants	50,292	61,569	58,869	59,553	[r] 54,971	54,189
At U.S. docks	5,558	6,839	6,100	6,429	5,347	3,741
Manganiferous iron ore (5 to 35 percent Mn):						
Shipments	616	588	201	302	485	213
Value	$4,242	$4,466	$1,480	W	W	W
World: Production	402,025	513,926	494,689	499,110	513,661	566,716

[r] Revised. W Withheld to avoid disclosing individual company confidential data.

[1] Direct shipping ore, washed ore, concentrates, agglomerates, and byproduct pyrites cinder and agglomerates.

[2] Includes byproduct ore.

[3] Excludes byproduct ore.

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[1] Commodity specialist, Division of Minerals.

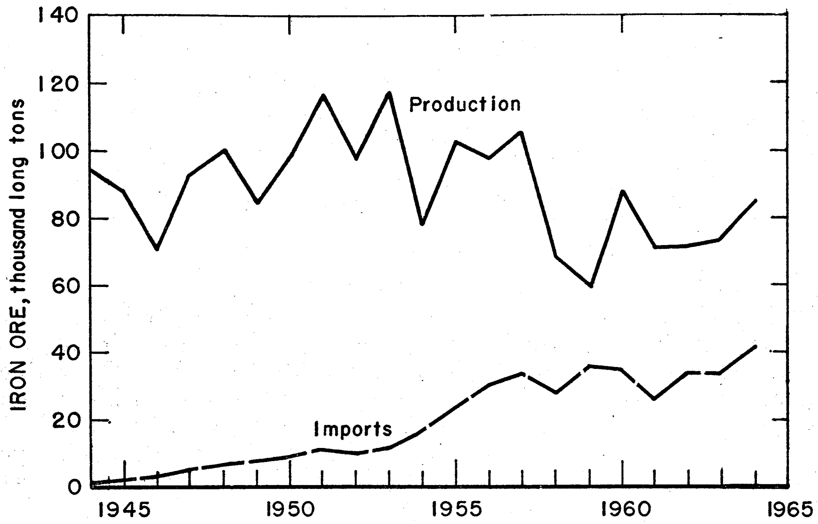

FIGURE 1.—United States iron ore production and imports for consumption.

EMPLOYMENT

Indicated productivity in terms of contained iron was 14 percent higher in 1963 than in 1962. The comparable gain in productivity was 11 percent in terms of usable ore, and 15 percent in terms of crude ore. The sharp increase in all categories reflects increasing output from open pit mines and decreasing output from underground mines. The transition resulted in more accurate employment data, but true productivity was still obscured by the practice of mining companies maintaining a stable labor force by keeping men employed the year-round, whether or not they are producing iron ore.

TABLE 2.—Employment at iron ore mines and beneficiating plants, quantity and tenor of ore produced and average output per man in 1963, by districts and States

District and State	Average number of men employed	Employment					Production [1]									
		Time employed					Crude ore (thousand long tons)	Usable ore			Average per man					
		Average number of days	Total man shifts (thousands)	Man hours			(Thousand long tons)	Iron contained [2]		Crude ore		Usable ore			
				Average per shift	Total (thousands)			(Thousand long tons)	Natural (percent)	Per shift	Per hour	Per shift	Per hour	Iron contained	
														Per shift	Per hour
Lake Superior:															
Minnesota	8,696	272	2,369	8.0	18,952	100,896	45,763	25,704	56.17	42.59	5.32	19,32	2.41	10.85	1.36
Michigan Wisconsin	3,577	253	904	8.0	7,232	16,946	10,764	6,149	57.13	18.75	2.34	11.91	1.49	6.85	.85
Total	12,273	267	3,273	8.0	26,184	117,842	56,527	31,853	56.35	36.00	4.50	17.27	2.16	9.73	1.22
Southeastern States:															
Alabama and Georgia	815	222	181	8.3	1,497	6,547	2,419	890	36.79	36.17	4.37	13.36	1.62	4.92	.59
Northeastern States:															
New Jersey, New York, Pennsylvania	2,706	256	692	8.3	5.735	11,344	4,922	3,107	63,13	16.39	1.98	7.11	.86	4.49	.54
Western States:															
Idaho, Montana, Wyoming	421	314	132	8.0	1,057	4,115	1,623	898	55.33	31.17	3.89	12.30	1.54	6.80	.85
Missouri	704	242	170	8.1	1,374	956	369	194	52.63	5.62	.70	2.17	.27	1.14	.14
Nevada and Utah	449	229	103	8.1	839	2,733	2,539	1,410	55.53	26.53	3.26	24.65	3.03	1.37	1.68
Total [3]	1,574	257	405	8.1	3,270	7,805	4,531	2,502	55.22	19.27	2.39	11.19	1.39	6.18	.77
Undistributed [4]	831	238	198	8.0	1,580	9,766	4,838	2,667	55.12	49.32	6.18	24.43	3.06	1.35	1.69
Grand total	18,199	261	4,749	8.1	38,266	153,304	73,237	41,019	56.01	32.28	4.01	15.42	1.91	8.64	1.07

[1] Includes manganese bearing ore in the Lake Superior district.

[2] Average iron content of all types of ore shipped.

[3] In some instances data do not add to totals due to rounding.

[4] Includes Arizona, Arkansas, California, Colorado, New Mexico, Tennessee, Texas, and Washington.

DOMESTIC PRODUCTION

Domestic iron mines produced 14 percent more crude ore in 1964 than in 1963. Twelve million tons of the increase was hematite, and 18 million tons of it was produced in open pit mines. The increased output of 1964 came from 21 less mines than the number operating in 1963, as only 158 iron mines reported to the Bureau of Mines in 1964.

Usable iron ore production was 15 percent more than in 1963. Six thousand tons of the increase was hematite. The ratio of concentration was 2.05 : 1, slightly less than that in 1963; however, the average grade of usable ore produced was 56 percent iron, 1 percent more than 1963.

Voters in Minnesota approved an amendment to their constitution which provides that taxes on taconite mining companies will not be increased above the general taxes on other industries of the State. Subsequently, the United States Steel Corp. announced that it would build a 4.5 million ton per year capacity plant on the Mesabi Range, at Mountain Iron. The Hanna Mining Co., Inland Steel Company, and Wheeling Steel Corp. announced that they would build a 2 million ton annual capacity plant on the Mesabi Range at Cooley. National Steel Corp. and Hanna Mining Co. announced plans to construct a 2.4 million ton capacity taconite plant on the Mesabi Range near Keewatin. And Jones & Laughlin Steel Corp. announced plans to build a 1.5 million ton capacity plant on the Mesabi Range between Biwabik and McKinley.

The Eveleth Taconite Co. owned jointly by Ford Motor Co. and Oglebay Norton Co. began construction of a 1.5 million ton annual capacity taconite plant on the Mesabi Range at Eveleth. The aforementioned taconite processing plants will increase Minnesota's capacity to produce taconite pellets by 12 million tons annually.

Three taconite-type iron-ore processing plants with a capacity of 3.8 million tons of high-grade concentrate or pellets, were completed during the year. The Merrimac Iron Ore project at Pea Ridge, near Sullivan, Mo., with capacity to produce 2 million tons of high-grade pellets annually was dedicated on April 11. The Empire Mining Complex on the Marquette Range, Mich., with a capacity to produce 1.2 million tons of high-grade pellets annually, was dedicated on April 16. And The Colorado Fuel and Iron Corp. concentrating plant at Sunrise, Wyo., with a capacity to produce 600,000 tons of high-grade concentrates annually was completed in December.

Reserve Mining Co., the first large-scale producer of taconite pellets, shipped its 50th million ton of pellet. The company's Peter Mitchell mine received the Sentinels of Safety trophy after having established a record of 3.7 million consecutive man-hours worked without lost-time injury.

TABLE 3.—Crude iron ore mined in the United States, by districts, States, and varieties

(Thousand long tons and exclusive of ore containing 5 percent or more manganese)

District and State	1963					1964				
	Number of mines	Hematite	Brown ore	Magnetite	Total [1]	Number of mines	Hematite	Brown ore	Magnetite	Total [1]
Lake Superior:										
Michigan	20	16,518	---	---	16,518	16	22,653	---	W	22,653
Minnesota	71	49,283	970	50,131	100,384	57	54,085	779	55,216	110,080
Wisconsin	2	413	---	---	413	1	376	---	---	376
Total	93	66,213	970	50,131	117,314	74	77,114	779	55,216	133,109
Southeastern States:										
Alabama	24	1,285	4,248	---	5,533	22	1,403	4,104	---	5,507
Georgia	8	---	1,015	---	1,015	11	---	1,393	---	1,393
Total	32	1,285	5,262	---	6,547	33	1,403	5,497	---	6,901
Northeastern States:										
New Jersey, New York, Pennsylvania	8	---	---	11,344	11,344	8	---	---	12,678	12,678
Western States:										
Colorado	---	---	W	---	W	5	---	35	W	35
Idaho	3	6	---	W	6	1	3	---	---	3
Missouri	8	956	W	---	956	5	---	W	1,797	1,797
Montana	2	---	---	13	13	1	---	---	15	15
Nevada	7	W	---	951	951	6	W	---	1,121	1,121
Utah	6	1,782	---	W	1,782	7	2,237	---	W	2,237
Wyoming	4	W	---	4,096	4,096	4	W	---	4,191	4,191
Total [1]	30	2,744	W	5,060	7,805	29	2,240	35	7,124	9,399
Undistributed [2]	16	6,131	3,569	66	9,766	14	W	W	11,528	11,528
Grand total [1]	179	76,373	9,801	66,601	152,776	158	80,757	6,311	86,547	173,615

W Withheld to avoid disclosing individual company confidential data.

[1] In some instances data do not add to totals due to rounding.

[2] Includes Arizona, Arkansas, California, New Mexico, Texas, for 1963 and 1964, also Colorado and Tennessee for 1963.

TABLE 4.—Crude iron ore mined in the United States, by districts, States, and mining methods

[Thousand long tons and exclusive of ore containing 5 percent or more manganese]

District and State	1963			1964		
	Open pit	Underground	Total[1]	Open pit	Underground	Total[1]
Lake Superior:						
Michigan	10,604	5,914	16,518	16,534	6,119	22,653
Minnesota	99,094	1,289	100,384	108,663	1,417	110,080
Wisconsin	----------	413	413	----------	376	376
Total	109,698	7,616	117,314	125,198	7,912	133,109
Southeastern States:						
Alabama	5,533	W	5,533	4,237	1,271	5,507
Georgia	1,015	----------	1,015	1,393	----------	1,393
Total	6,547	W	6,547	5,630	1,271	6,901
Northeastern States:						
New Jersey, New York, Pennsylvania	11,344	W	11,344	12,678	W	12,678
Western States:						
Colorado	W	----------	W	35	----------	35
Idaho	6	----------	6	3	----------	3
Missouri	W	956	956	W	1,797	1,797
Montana	13	----------	13	15	----------	15
Nevada	951	W	951	1,121	W	1,121
Utah	1,782	----------	1,782	2,237	----------	2,237
Wyoming	4,096	W	4,096	4,191	W	4,191
Total	6,848	956	7,805	7,602	1,797	9,399
Undistributed[2]	9,766	----------	9,766	11,528	----------	11,528
Grand total[1]	144,204	8,572	152,776	162,635	10,979	173,615

W Withheld to avoid disclosing individual company confidential data.

[1] In some instances data do not add to totals due to rounding.

[2] Includes Arizona, Arkansas, California, New Mexico, Texas for 1963 and 1964, also Colorado and Tennessee for 1963.

TABLE 5.—Crude iron ore shipped from mines in the United States, by districts, States, and disposition

(Thousand long tons and exclusive of ore containing 5 percent or more manganese)

District and State	1963			1964		
	Direct to consumers	To beneficiation plants	Total [1]	Direct to consumers	To beneficiation plants	Total [1]
Lake Superior:						
Michigan	4,852	11,842	16,694	5,753	17,982	23,735
Minnesota	7,468	93,082	100,550	10,441	99,582	110,023
Wisconsin	938		938	524		524
Total	13,258	104,925	118,183	16,718	117,563	134,281
Southeastern States:						
Alabama	W	5,533	5,533	275	5,166	5,442
Georgia		1,015	1,015		1,393	1,393
North Carolina	1		1			
Total	1	6,548	6,549	275	6,560	6,835
Northeastern States:						
New Jersey, New York, Pennsylvania		11,543	11,543		12,549	12,549
Western States:						
Colorado	W		W	35		35
Idaho	6		6	4		4
Missouri		934	934		1,920	1,920
Montana	13		13	15		15
Nevada	443	508	951	W	1,121	1,121
Utah	2,046	W	2,046	2,406	W	2,406
Wyoming	W	4,096	4,096	W	4,185	4,185
Total	2,508	5,538	8,046	2,459	7,227	9,686
Undistributed [2]	67	9,745	9,811	W	11,423	11,423
Grand total [1]	15,834	138,297	154,131	19,452	155,322	174,774

W Withheld to avoid disclosing individual company confidential data.

[1] In some instances data do not add to totals due to rounding.

[2] Includes Arizona, Arkansas, California, New Mexico, and Texas for 1963–64, also Colorado and Tennessee for 1963.

TABLE 6.—Usable iron ore produced in the United States, by districts, States, and varieties

(Thousand long tons and exclusive of ore containing 5 percent or more manganese)

District and State	1963				1964			
	Hematite	Brown ore	Magnetite	Total[1]	Hematite	Brown ore	Magnetite	Total[1]
Lake Superior:								
Michigan	10,336	----	----	10,336	13,677	----	W	13,677
Minnesota	28,845	W	16,538	45,383	30,331	425	18,298	49,054
Wisconsin	413	----	----	413	376	----	----	376
Total	39,594	W	16,538	56,132	44,382	425	18,298	63,106
Southeastern States:								
Alabama	1,103	1,062	----	2,165	1,166	1,027	----	2,192
Georgia	----	254	----	254	----	354	----	354
Total	1,103	1,316	----	2,419	1,166	1,379	----	2,545
Northeastern States:								
New Jersey, New York, Pennsylvania	----	----	4,922	4,922	----	----	5,214	5,214
Western States:								
Colorado	----	W	W	W	----	W	35	35
Idaho	6	----	W	6	3	----	----	3
Missouri	369	W	----	369	W	W	1,110	1,110
Montana	----	----	13	13	----	----	15	15
Nevada	W	----	772	772	W	----	911	911
Utah	1,767	----	W	1,767	2,052	----	W	2,052
Wyoming	W	----	1,604	1,604	W	----	2,061	2,061
Total	2,141	W	2,390	4,531	2,055	W	4,132	6,187
Undistributed[2]	3,672	1,125	41	4,838	W	W	6,748	6,748
Total all States	46,509	2,443	23,891	72,841	47,603	1,804	34,392	83,799
Byproduct ore[3]	----	----	----	757	----	----	----	1,032
Grand total	46,509	2,443	23,891	73,599	47,603	1,804	34,392	84,836

W Withheld to avoid disclosing individual company confidential data.

[1] In some instances data do not add to totals because of rounding.

[2] Includes Arizona, Arkansas, California, New Mexico, Texas, for 1963-64, also Colorado and Tennessee for 1963.

[3] Cinder and sinter obtained from treating pyrites. Ore was treated in Arizona, Colorado, Delaware (1964), Pennsylvania, Tennessee, Texas (1964), and Virginia.

TABLE 7.—Usable iron ore produced in the United States, by districts, States, and types of products

(Thousand long tons and exclusive of ore containing 5 percent or more manganese)

District and State	1963				1964			
	Direct shipping ore	Agglomerates [1]	Concentrates	Iron content (natural percent) [2]	Direct shipping ore	Agglomerates	Concentrates	Iron content (natural percent) [2]
Lake Superior:								
Michigan	4,574	4,414	1,348	57	5,489	6,683	1,505	58
Minnesota	7,336	16,619	21,428	56	10,442	18,481	20,131	56
Wisconsin	413	--------	--------	56	376	--------	--------	56
Total	12,323	21,032	22,777	56	16,307	25,164	21,636	56
Southeastern States:								
Alabama	327	--------	1,838	37	341	--------	1,851	35
Georgia	--------	--------	254	47	--------	--------	354	46
Total	327	--------	2,092	37	341	--------	2,205	37
Northeastern States:								
New Jersey, New York Pennsylvania	--------	3,798	1,125	63	--------	4,408	806	64
Western States:								
Colorado	W	--------	--------	W	35	--------	--------	60
Idaho	6	--------	--------	49	3	--------	--------	33
Missouri	--------	--------	369	53	--------	811	299	64
Montana	13	--------	--------	42	15	--------	--------	45
Nevada	772	--------	W	62	911	--------	W	61
Utah	1,767	--------	W	53	2,052	--------	W	53
Wyoming	W	1,604	W	55	2,061	W	--------	50
Total	2,558	1,604	369	55	5,077	811	299	55
Undistributed [3]	11	W	4,827	55	W	331	6,417	56
Total all States	15,218	26,435	31,189	56	21,724	30,714	31,361	56
Byproduct ore [4]	--------	757	--------	68	--------	1,032	--------	69
Grand total	15,218	27,192	31,189	56	21,724	31,746	31,361	57

W Withheld to avoid disclosure of individual company data.

[1] Exclusive of agglomerates produced at consuming plants.

[2] Average content of all types shipped. For breakdown by type, see table 8.

[3] Includes Arizona, Arkansas, California, New Mexico and Texas for 1963 and 1964, also Colorado and Tennessee for 1963.

[4] Cinder and sinter obtained from treating pyrites.

TABLE 8.—Shipments of usable iron ore from mines in the United States in 1964

(Thousand long tons and thousand dollars; exclusive of ore containing 5 percent or more manganese)

District and State	Gross weight of ore shipped				Iron content of ore shipped				Total value [1]
	Direct shipping ore	Agglomerates	Concentrates	Total quantity [1]	Direct shipping ore	Agglomerates	Concentrates	Total quantity [1]	
Lake Superior:									
Michigan	5,753	6,573	1,546	13,871	3,337	3,812	897	8,046	$143,979
Minnesota	10,441	19,267	19,917	49,626	5,847	10,790	11,154	27,791	449,289
Wisconsin	524	-----	-----	524	293	-----	-----	293	W
Total	16,718	25,840	21,463	64,021	9,477	14,602	12,051	36,130	593,268
Southeastern States:									
Alabama	275	-----	1,831	2,106	96	-----	641	737	11,812
Georgia	-----	-----	354	354	-----	-----	163	163	1,752
Total	275	-----	2,185	2,461	96	-----	804	900	13,564
Northeastern States:									
New Jersey, New York, Pennsylvania	-----	4,414	530	4,944	-----	2,824	339	3,163	71,095
Western States:									
Colorado	35	-----	-----	35	21	-----	-----	21	231
Idaho	4	-----	-----	4	1	-----	-----	1	33
Missouri	-----	1,116	W	1,116	-----	718	W	718	14,907
Montana	15	-----	-----	15	7	-----	-----	7	99
Nevada	911	-----	W	911	556	-----	W	556	5,048
Utah	1,651	-----	432	2,082	875	-----	229	1,104	14,306
Wyoming	W	2,056	-----	2,056	W	1,028	-----	1,028	24,543
Total	2,615	3,172	432	6,218	1,460	1,746	229	3,435	59,167
Undistributed [2]	W	W	6,656	6,656	W	W	3,746	3,746	65,238
Total all States	19,608	33,425	31,266	84,300	11,033	19,172	17,169	47,374	802,331
Byproduct ore [3]	-----	884	-----	884	-----	600	-----	600	11,007
Grand total	19,608	34,309	31,266	85,184	11,033	19,772	17,169	47,974	813,338

W Withheld to avoid disclosing individual company confidential data.

[1] In some instances data do not add to totals due to rounding.

[2] "Undistributed" includes totals for Arizona, Arkansas, California, New Mexico, and Texas and value for Wisconsin.

[3] Cinder and sinter obtained from treating pyrites. Ore treated in Arizona, Colorado, Delaware, Pennsylvania, Tennessee, and Virginia.

TABLE 9.—Iron ore produced in the Lake Superior district, by ranges

(Thousand long tons and exclusive after 1905 of ore containing 5 percent or more manganese)

Year	Marquette	Menominee	Gogebic	Vermillion	Mesabi	Cuyuna	Total
1854–1959	302,817	263,668	308,285	[1] 93,566	2,236,801	[2] 63,923	3,269,060
1960	6,619	4,079	3,653	[3] 1,834	54,441	1,166	71,792
1961	3,205	4,097	2,190	[3] 1,421	41,199	1,095	53,207
1962	4,563	3,460	2,318	[3] 1,521	43,039	655	55,556
1963	5,706	3,729	1,314	[3] 1,298	43,570	515	56,132
1964	7,898	4,551	1,602	[3] 1,285	47,256	513	63,106
Total [4]	330,808	283,584	319,362	100,925	2,466,306	67,867	3,568,853

[1] Production for 1957 and 1959 included with Mesabi range.
[2] Includes production from Spring Valley district in 1959.
[3] Includes production from Spring Valley district not in the true Lake Superior district.
[4] In some instances data do not add to total due to rounding.

TABLE 10.—Average analyses of total tonnages (bill-of-lading weights) of all grades of iron ore from all ranges of Lake Superior district

Year	Thousand long tons	Content (natural), percent					
		Iron	Phosphorus	Silica	Manganese	Moisture	Alumina [1]
1955–59 (average)	68,345	52.05	0.090	9.50	0.65	9.80	
1960	67,439	53.84	.083	8.90	.63	8.26	
1961	55,403	55.20	.080	8.60	.56	7.19	1.21
1962	55,010	55.60	.077	8.45	.51	7.04	1.24
1963	57,591	56.34	.074	8.19	.52	6.30	1.10
1964	64,222	56.67	.073	8.13	.45	6.17	1.09

[1] Alumina analyses not available prior to 1961.

TABLE 11.—Beneficiated iron ore shipped from mines in the United States [1]

(Thousand long tons and exclusive of ore containing 5 percent or more manganese)

Year	Beneficiated	Total	Proportion of beneficiated to total (percent)
1955–59 (average)	33,323	86,406	38.6
1960	46,012	82,963	55.5
1961	46,125	72,379	63.7
1962	46,942	69,969	67.1
1963	57,177	73,564	77.7
1964	64,329	84,300	76.3

[1] Excludes byproduct ore

CONSUMPTION AND USES

Iron ore concentrate used to make agglomerate at the mines is material in the process of being beneficiated from crude to usable ore; such use is not reported as iron ore consumption. On the other hand, iron ore fines and iron ore concentrate used to make agglomerate (principally sinter) at steel mills has been beneficiated from crude to usable ore. Accordingly material used for this purpose is reported as iron ore consumption. This method of reporting was adopted in 1963. It leads to a valid balance betweeen consumption and iron ore production plus imports less exports, considering processing losses and ore lost in transit.

Iron ore consumed in making agglomerate at steel mills included foreign and domestic direct-shipping ores, fines generated in shipping, and foreign and domestic iron ore concentrate. Other materials such as limestone, flue dust, mill scale, and coke breeze used in making agglomerates are excluded from iron ore consumption.

Consumption data listed in the miscellaneous category included iron ore used in making cement and special high-density concrete and for paint pigments and heavy medium in coal processing plants.

TABLE 12.—Consumption of iron ore and agglomerates in the United States in 1964

(Long tons and exclusive of ore containing 5 percent or more manganese)

	Iron ore [1]		Agglomerates [2]		Miscellaneous [3]	Total
	Blast furnaces	Steel furnaces	Blast furnaces	Steel furnaces		
Alabama, Kentucky, Tennessee Texas	6,801,589	365,009	4,180,904	W	95,958	11,443,460
California, Colorado, Utah	4,310,488	550,304	2,902,577	----------	93,670	7,857,039
Maryland and West Virginia	4,526,244	706,879	6,504,544	----------	(4)	11,737,667
Illinois and Indiana	14,164,363	2,122,664	11,384,000	W	102,457	27,773,484
Michigan and Minnesota	7,813,697	195,356	3,330,893	----------	(4)	11,339,946
New York, Ohio, Pennsylvania, New Jersey	37,134,967	3,384,540	20,666,298	W	230,069	61,415,874
Undistributed [5]	----------	----------	----------	647,836	112,448	760,284
Total	74,751,348	7,324,752	48,969,216	647,836	634,602	132,327,754

W Withheld to avoid disclosing individual company data.

[1] Includes 22 million tons of pellets and nodules produced at mines.

[2] Does not include agglomerates produced at mine site.

[3] Includes iron ore used in making paint and cement, also ore consumed in ferroalloy furnaces.

[4] Included with Illinois and Indiana.

[5] Includes items indicated by footnote W.

TABLE 13.—Iron ore[1] consumed in agglomerating plants and agglomerate produced in 1964, by States

(Long tons)

State	Iron ore[1] consumed	Agglomerate produced
Alabama, Kentucky, Texas	3,188,115	4,125,773
California, Colorado, Utah	2,417,446	2,900,088
Maryland and West Virginia	5,886,029	6,148,867
Illinois and Indiana	10,318,722	11,490,918
Michigan and Minnesota	2,590,191	3,296,491
New York, Ohio, Pennsylvania	16,141,579	17,631,528
Total	40,542,082	45,593,665

[1] Does not include material used in agglomerate produced at mine site.

TABLE 14.—Production of agglomerates[1] in the United States in 1964, by types

(Long tons)

Type	Agglomerate produced
Sinter[2]	48,488,292
Pellets	28,818,305
Nodules	(3)
Total	77,306,597

[1] Production at mines and consuming plants.
[2] Includes 16,049,000 tons of self-fluxing sinter.
[3] Included with pellets.

STOCKS

Iron ore stocks at mines, U.S. docks, and consuming plants including byproduct ore totaled 68.7 million long tons on December 31, 1964, 2.5 million tons less than at the same time in 1963. Mine stocks of 10 million tons were principally in the Lake Superior district and were about normal, considering the seasonal shipping and year-round operation of the taconite plants. Inventory at consuming plants totaled 54 million long tons a little less than in 1963, but probably more than needed. On the other hand, iron ore stocks of 4 million long tons at U.S. docks reported by the American Ore Association were less than at any time since World War II.

TABLE 15.—Stocks of usable iron ore at mines[1] Dec. 31, by districts

(Thousand long tons)

District	1963	1964
Lake Superior	[r] 7,744	6,829
Southeastern States	97	179
Northeastern States	[r] 2,205	2,475
Western States	[r] 692	759
Total[2]	[r] 10,738	10,241

[r] Revised.
[1] Excluding byproduct ore.
[2] Data for 1964 do not add to total because of rounding.

PRICES

Quoted base prices for Lake Superior iron ore were $0.10 less per ton in 1964 than in 1963 owing to a corresponding decrease in lake vessel freight rates in 1963. Prices for iron ore containing 51.5 percent iron, natural, rail of vessel at lower lake ports per long ton were as follows: Mesabi non-Bessemer $10.65, Mesabi Bessemer $10.70, Old Range non-Bessemer $10.80, and Old Range Bessemer $10.95. Lake Superior pellets were quoted at $0.252 per long ton unit. E&MJ Metal and Mineral Markets quoted open-hearth lump iron ore at $12.60 per long ton, Brazilian ore effective Jan. 10, 1964 (68.5 percent iron) lumps $10.40, run-of-mine (64 percent iron) $8, pebble (64 percent iron) $9.15, fines (64 percent iron) $6.10. The Brazilian ore prices are f.o.b.

The average value of domestic usable ore per long ton f.o.b. mines, excluding byproduct ore, was $9.52, compared with $9.22 in 1963, and $8.84 in 1962. These values were compiled from producers' statements and approximate the commercial selling price less the cost of mine-to-market transportation.

TABLE 16.—Average value per long ton of iron ore shipped from mines in the United States in 1964

District	Direct-shipping ore			Concentrates			Agglomerates
	Hematite	Brown ore	Magnetite	Hematite	Brown ore	Magnetite	
Lake Superior	$7.20	(1)	----------	$7.74	(1)	----------	$12.04
Southeastern	W	----------	----------	(2)	$5.47	----------	----------
Northeastern	----------	----------	----------	----------	----------	$13.93	14.43
Western	6.27	----------	$6.96	8.20	12.14	5.17	14.89
Total	7.11	----------	6.96	7.84	8.28	10.02	12.56

W Withheld to avoid disclosing individual company confidential data.
[1] Included with hematite.
[2] Included with brown ore.

TRANSPORTATION

A large part of the activities in iron ore transportation reported in 1964 had to do with reducing costs. Long distance pipeline transportation was much discussed, especially in connection with reducing the cost of moving iron ore concentrates from the Lake Superior region to the steel mills in Illinois, Pennsylvania, and Ohio.

Railroads apparently foreseeing possible competition put unit trains and special ore cars in service, and 9 miles of railroad line with about 7 miles of passing track and yards were constructed on the Upper Peninsula of Michigan to serve iron mines on the Marquette Range. A computer was installed on the Great Lakes iron ore carrier the *William G. Mather* to replace three firemen on the ship. It was expected that as much as $1 million will be saved over the remaining life of the 39-year-old ship.

The National Council of Applied Economic Research, in a study of the cost price structure of iron ore for the Ministry of Commerce and Industry of the Government of India, estimated ocean freight costs in various size carriers[2] as follows:

Vessel, tonnage:	*Cost per ton, per 1,000 nautical miles*
10,000	$1.35
30,000	.97
35,000	.896
85,000	.476

Iron ore again was moved on the St. Lawrence Seaway and Welland Canal at record rates. Shipments totaled 16,830,620 tons, 12,726,631 tons of ore passed upstream through the canal, and 4,103,989 tons downstream. Essentially all the upbound ore went to the United States, and all the downbound ore went to Canada.

Freight Rates.—Lake vessel freight rates from upper Lake Superior ports to the lower lake ports were unchanged in 1964. Rates from the Minnesota Ranges to the Pittsburgh district totaled $6.60 per long ton. Component charges were $1.28 rail from the Ranges to Duluth-Superior, $0.19 handling charge, $1.90 Duluth-Superior to lower lake ports, $0.28 hold to rail of vessel, $0.22 rail of vessel to car, and $2.73 rail lower lake ports to the Pittsburgh district. All rail rates from the Minnesota Ranges to the Pittsburgh district were $10.23 per long ton. The freight rate from the Eastern seaboard to the Pittsburgh district was $3.76 per long ton plus $0.55 per ton unloading charges, vessel to car.

FOREIGN TRADE

U.S. iron ore trade was valued as $500 million in 1964. Exports changed very little compared with those in 1963, but imports increased by almost 10 million tons with an increased value of $100 million. Imports from Canada and Liberia accounted for most of the increase as new iron mining facilities in those countries began to produce at capacity.

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[2] National Council of Applied Economic Research (New Delhi, India). Cost Price Structure of Iron Ore, January 1965, 102 pp.

TABLE 17.—U.S. imports for consumption of iron ore,[1] by countries

(Thousand long tons and thousand dollars)

Country	1955–59 (average)		1960		1961		1962		1963		1964	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
North America:												
Canada	11,617	$102,954	10,595	$104,709	9,683	$99,164	16,825	$169,765	18,891	$199,416	24,854	$274,548
Mexico	175	572	150	513	123	421	145	546	1	5	22	129
Other	134	1,576	3	30	------	------	------	------	------	------	(2)	(2)
Total	11,926	105,102	10,748	105,252	9,806	99,585	16,970	170,311	18,892	199,421	24,876	274,677
South America:												
Brazil	1,139	14,505	1,461	15,518	889	9,613	1,299	14,080	781	7,731	1,055	11,660
Chile	2,438	18,105	3,942	30,684	2,604	21,913	3,400	28,907	2,679	25,332	2,712	24,220
Peru	1,936	17,819	2,758	26,828	1,209	11,752	573	6,196	290	2,406	580	6,646
Venezuela	10,886	77,507	14,555	133,138	10,478	99,118	10,328	96,981	9,231	76,937	9,954	79,207
Other	(2)	5	------	------	------	------	------	------	------	------	8	79
Total	16,399	127,941	22,716	206,168	15,180	142,396	15,600	146,164	12,981	112,406	14,309	121,812
Europe:												
Sweden	629	7,440	94	1,543	78	1,156	32	566	37	742	93	1,109
United Kingdom	5	76	(2)	29	2	147	------	------	------	------	------	------
Other	3	37	1	20	1	10	1	24	(2)	13	10	477
Total	637	7,553	95	1,592	81	1,313	33	590	37	755	103	1,586
Asia:												
Iran	2	124	2	133	------	------	------	------	------	------	2	166
Philippines	30	601	1	22	------	------	49	1,018	22	367	------	------
Other	------	------	57	367	(2)	1	(2)	12	(2)	1	------	------
Total	32	725	60	522	(2)	1	49	1,030	22	368	2	166

Africa:												
British West Africa	116	788	46	315	----------	----------	----------	----------	----------	----------	----------	----------
Liberia	1,020	9,204	907	8,034	715	6,728	757	6,478	1,310	9,944	2,873	20,297
Mauritania	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	133	1,618
Nigeria	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	72	666
Other	9	99	6	36	23	203	----------	----------	21	264	39	457
Total	1,145	10,091	959	8,385	738	6,931	757	6,478	1,331	10,208	3,117	23,038
Oceania: Australia	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	1	9
Grand total	30,139	251,412	34,578	321,919	25,805	250,226	33,409	324,573	33,263	323,158	42,408	421,288

[1] In addition pyrites cinder (byproduct iron ore) was imported as follows: 1955–59 (average) 3,068 long tons ($11,239); 1960, 5,884 tons ($19,679); 1961, 3,504 tons ($17,822); 1962, 4,248 tons ($26,345) all from Canada; 1963, Canada 3,489 tons ($46,057), West Germany 22 tons ($2,294); 1964, 8,635 tons ($49,266) all from Canada.

[2] Less than ½ unit.

Source: Bureau of the Census.

TABLE 18.—U.S. imports for consumption of iron ore, by customs districts

Customs district	1963		1964	
	Long tons	Value	Long tons	Value
Buffalo	1,602,438	$19,376,294	2,578,887	$29,218,104
Chicago	3,016,544	31,384,520	4,659,345	47,793,095
Dakota	66	2,946	------------	------------
Duluth and Superior	200	1,258	228	1,351
Galveston	396,657	4,805,849	689,301	8,923,344
Laredo	1,021	4,831	21,604	128,823
Maryland	8,835,105	76,617,494	8,991,885	81,124,132
Michigan	1,419,761	17,174,788	2,763,367	37,329,044
Mobile	2,672,041	21,874,484	3,010,260	24,506,883
New Orleans	525,686	4,157,437	607,121	5,470,234
New York	241	1,635	4,501	36,143
Ohio	5,339,799	55,524,801	5,947,880	64,015,475
Philadelphia	9,059,750	88,512,535	12,578,575	117,289,584
St. Lawrence	9,649	162,353	26,471	426,547
South Carolina	------------	------------	15	1,603
Vermont	84	7,894	411	38,813
Virginia	383,470	3,545,364	528,001	4,982,008
Washington	325	2,884	236	2,463
Wisconsin	55	262	4	300
Total	33,262,892	323,157,629	42,408,092	421,287,946

Source: Bureau of the Census.

TABLE 19.—U.S. exports of iron ore, by countries

(Thousand long tons and thousand dollars)

Destination	1955-59 (average)		1960		1961		1962		1963		1964	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
Canada	3,649	$33,622	4,428	$48,989	3,889	$42,269	4,781	$51,377	4,987	$58,054	4,834	$58,586
Germany, West	------	------	(1)	(1)	172	1,993	64	340	72	423	73	432
Japan	660	6,602	839	8,622	883	9,655	981	10,213	1,682	17,087	2,021	20,247
South Africa, Republic of	2	107	4	174	4	179	5	164	3	155	1	44
United Kingdom	------	------	------	------	6	70	64	714	65	605	18	260
Other	2	82	2	114	4	64	3	39	r 3	r 16	16	101
Total	4,313	40,413	5,273	57,899	4,958	54,230	5,898	62,847	r 6,812	r 76,340	6,963	79,670

r Revised.

[1] Less than ½ unit.

Source: Bureau of the Census.

WORLD REVIEW

Increased activity in the steel industries of European countries, the United States, and Japan resulted in the market absorbing most of the surplus supply of iron ore. Producers of conventional direct shipping ores again were able to market most of their output. Some mines that for several years had been operating substantially below capacity resumed normal operations. Mining companies planning operations in Western Australia announced firm plans to construct plants with capacity to produce more than 12 million tons of high-grade iron ore concentrate, or iron ore pellets annually.

TABLE 20.—World production of iron ore, iron ore concentrates, and iron ore agglomerates by countries [1]

(Thousand long tons)

Country	1955-59 (average)	1960	1961	1962	1963	1964 [p]
North America:						
Canada	18,057	19,242	18,178	24,428	26,914	34,522
Cuba	92	[e] 3	[e] 2	[e] 1	[e] 1	[e] 1
Dominican Republic	96	121	---	---	---	---
Guatemala [e]	4	4	5	5	6	7
Mexico (60 percent Fe equivalent)	854	855	1,127	1,790	2,291	2,160
United States [2]	87,003	88,784	71,329	71,829	73,599	84,836
Total	106,106	109,009	90,641	98,053	102,811	121,526
South America:						
Argentina	75	133	137	119	93	93
Brazil	5,221	9,197	10,059	10,567	11,042	[e] 14,763
Chile	3,013	5,946	6,879	7,964	8,373	9,697
Colombia	454	645	665	669	684	699
Peru	2,976	6,880	8,599	5,855	6,470	6,501
Venezuela	13,309	19,182	14,335	13,057	11,562	15,403
Total	25,048	41,983	40,674	38,231	38,224	47,156
Europe:						
Albania	[3] 100	251	352	418	[e] 295	[e] 344
Austria	3,225	3,486	3,635	3,692	3,675	3,507
Belgium	129	157	113	80	94	60
Bulgaria	258	405	411	625	645	705
Czechoslovakia	2,678	3,071	3,242	3,422	3,357	2,801
Finland [4]	206	269	276	299	360	[e] 463
France	55,354	65,907	65,554	65,254	56,978	59,971
Germany:						
East	1,575	1,616	1,617	1,616	1,635	1,624
West	17,121	18,571	18,568	16,380	12,694	11,430
Greece	273	292	287	209	35	[e] 59
Hungary	363	508	595	671	721	763
Italy	1,413	1,242	1,216	1,133	987	900
Luxembourg	7,045	6,867	7,340	6,404	6,880	6,575
Norway	1,501	1,665	1,647	1,919	1,935	2,019
Poland	1,823	2,148	2,348	2,398	2,568	2,638
Portugal	233	297	230	229	221	169
Rumania	744	1,437	1,710	1,711	2,250	1,915
Spain	4,553	5,549	5,967	5,670	5,111	5,149
Sweden	18,285	21,348	23,220	21,675	23,259	26,116
Switzerland	101	[e] 123	[e] 85	[e] 102	94	89
U.S.S.R. [5] [6]	82,096	104,186	115,776	126,079	135,304	143,695
United Kingdom	15,802	17,088	16,518	15,277	14,912	16,068
Yugoslavia	1,789	2,165	2,150	2,155	2,261	2,271
Total [5]	216,667	258,648	272,857	277,418	276,271	289,331

See footnotes at end of table.

TABLE 20.—World production of iron ore, iron ore concentrates, and iron ore agglomerates by countries [1]—Continued

(Thousand long tons)

Country	1955–59 (average)	1960	1961	1962	1963	1964
Asia:						
Burma	4	16	e 16	9	----------	----------
China e [7]	20,900	54,100	34,400	29,500	34,400	36,400
Hong Kong	111	115	117	111	112	114
India	5,710	10,514	12,076	13,151	14,690	14,646
Goa	2,700	5,764	6,381	5,354	4,921	5,571
Iran [8]	45	57	41	10	----------	----------
Japan [9]	2,054	2,809	2,826	2,546	2,387	2,483
Korea:						
North	1,377	3,059	3,494	3,287	3,799	e 4,724
South	162	386	497	464	493	674
Lebanon	30	8	----------	----------	----------	----------
Malaysia	2,688	5,641	6,734	6,508	7,264	6,465
Pakistan [10]	[11] 10	6	4	----------	([12])	5
Philippines	1,289	1,121	1,153	1,365	1,363	1,345
Taiwan [13]	[11] 7	8	13	6	5	7
Thailand	8	11	55	44	16	15
Turkey	923	778	746	800	735	961
Total e [5]	38,000	84,400	68,600	63,200	70,200	73,400
Africa:						
Algeria	2,614	3,384	2,822	2,029	1,945	2,696
Angola	[11] 186	649	799	740	628	891
Guinea, Republic of	657	764	533	689	652	755
Liberia	2,164	3,003	3,200	3,550	[14] 6,453	10,291
Mauritania	----------	----------	295	984	1,407	4,523
Morocco	1,552	1,552	1,439	1,131	1,019	874
Rhodesia (formerly Southern)	120	156	382	609	645	811
Sierra Leone	1,319	1,447	1,668	1,843	1,882	1,962
South Africa, Republic of	2,213	3,023	3,898	4,263	4,390	4,754
Sudan	----------	3	5	20	----------	([12])
Swaziland	----------	----------	----------	----------	----------	59
Tunisia	1,100	1,017	836	749	851	924
United Arab Republic (Egypt)	[11] 199	237	415	454	473	440
Total	12,124	15,235	16,292	17,061	20,345	28,980
Oceania:						
Australia	3,869	4,355	5,342	4,843	5,515	6,021
Fiji	5	24	10	6	1	----------
New Caledonia	[11] 206	272	273	298	294	302
Total	4,080	4,651	5,625	5,147	5,810	6,323
World total e [1]	402,025	513,926	494,689	499,110	513,661	566,716

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e Estimate. p Preliminary.

[1] This table incorporates some revisions. Data do not add to totals shown because of rounding where estimated figures are included in the detail.

[2] Includes byproduct ore.

[3] Average annual production 1957–59.

[4] Iron concentrates and pellets.

[5] U.S.S.R. in Asia included with U.S.S.R. in Europe.

[6] Data represents iron concentrates of approximately 60 percent iron.

[7] Roughly equivalent of 50 percent iron.

[8] Year ending March 20 of year following that stated.

[9] Includes iron sand production as follows: 1955–59 (average), 952,406; 1960, 1,539,346; 1961, 1,685,137; 1962, 1,419,744; 1963, 1,274,748; and 1964, 1,366,499.

[10] Obtained principally during exploration activities.

[11] Average annual production 1956–59.

[12] Less than ½ unit.

[13] Principally magnetite sands with limonite.

[14] Exports.

TABLE 21.—World trade of iron ore, iron-ore concentrates, and iron-ore agglomerates in 1963

(Thousand long tons)

Exports by countries of origin	Fe (percent) [e]	Production	Exports	Exports by countries of destination																	
				North America		South America	Europe													Asia	
				Canada	United States	Argentina	Austria	Belgium-Luxembourg	Czechoslovakia	France	Germany, East	Germany, West	Hungary	Italy	Netherlands	Poland	Rumania	United Kingdom	Other Europe	Japan	Other countries
North America:																					
Canada	54	26,914	23,855		18,329			198				[e]815		68				2,466		1,979	
Mexico	60	2,291	1		1																
United States	54	[1]73,599	6,809	4,986								72		(2)				65	(2)	1,682	4
South America:																					
Brazil	68	11,042	8,137	394	828	303	164	41	652	[3]664		2,479	20	779	[4]24	333	106	769	72	509	
Chile	63	8,373	6,980	42	[3]2,679	153			3			207		328	[4]13					3,555	
Colombia	45	684	(2)		(2)																
Peru	60	6,470	5,647		251	112		69		[3]277		[3]1,347		407				289	32	2,857	6
Venezuela	62	11,562	12,158		9,181							1,028		587				1,362			
Europe:																					
Austria	32	3,675	(2)									(2)									
Belgium-Luxembourg	30	6,974	269							265					1				(2)		3
Bulgaria	62	645	14										1				13				
Finland	65	360	148						35							113					
France	30	56,978	20,869					13,855				6,755						259			(2)
Germany, West	27	12,694	282		(2)		267	2		8				(2)	3			(2)	2		(2)
Greece	50	35	50				5					36		9							
Italy	51	987	(2)																		(2)
Norway	60	1,935	1,203									[3]715				[3]84		[e]404			
Poland	34	2,568	3															2			1
Portugal	50	221	72					34				3		5				30			
Spain	50	5,111	1,959				50	40		147		894		41	349			417	20		1
Sweden	61	23,259	19,936		33		70	4,801	330	[3]617		7,668	18	511	384	531		4,588	384		1
Switzerland	40	94	88							(2)		88									
U.S.S.R.	60	[5]135,304	20,461				[3]388		6,805		2,406	[3]321	2,000			[e]6,934	1,607				
United Kingdom	28	14,912	NA																		
Yugoslavia	43	2,261	152								(2)		152								
Other East Europe		8,258	NA																		

Asia:																					
China	50	[e]34,400	NA																		
Hong Kong	56	112	130																	130	
India, including Goa	60	19,611	7,789					115	880	8	44	536	87	329	11	111	414	(2)	334	4,920	
Japan	56	2,387																			
Korea, South	50	493	550																	549	1
Malaysia	56	7,264	6,582																	6,510	72
Philippines	58	1,363	1,442																	1,442	
Turkey	51	735	12											12							
Other Asia		3,820	NA																		
Africa:																					
Algeria	54	1,945	1,928							65		134		627				924	174		4
Angola	65	628	645						21	1		532		38					2	51	
Guinea, Republic of	53	652	362						14		21					240		85			2
Liberia	62	[6]6,453	6,453		[3]1,310					[3]738		[3]1,629		[3]546	[3]673			[3]1,088			[3]469
Mauritania	65	1,407	1,230		25			37		406		258		283				209	12		
Morocco	58	1,019	1,062						198	133		172			38			275	246		
Rhodesia (formerly Southern)	57	645	207																	207	
Sierra Leone	64	1,882	1,954				29			88		499		(2)	797			541			(2)
South Africa, Republic of	65	4,390	680							24		13		41	3			500			(2)
Tunisia	54	851	769									[3]19		[3]193		[3]88		[3]294			175
United Arab Republic (Egypt)	50	473	NA																		
Oceania:																					
Australia	65	5,515	(2)																		(2)
Fiji	55	1	1																	1	
New Caledonia	55	294	290																		290
Other countries		115	(7)																		
Total		513,661	161,179	5,422	32,637	568	973	19,192	8,938	3,441	2,471	26,220	2,278	4,804	2,296	8,434	2,140	14,666	1,278	24,392	1,029

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[e] Estimate. NA Not available.
[1] Includes byproduct ore.
[2] Less than ½ unit.
[3] From import detail of customs returns of the respective country.
[4] Adjusted figure.
[5] U.S.S.R. in Asia included with U.S.S.R. in Europe.
[6] Exports.
[7] Incomplete data.

NORTH AMERICA

Canada.—Canada ranked fifth among the iron ore producing countries of the world in 1964. The industry continued its rapid growth of the last decade, but new developments were not as spectacular nor as large as those of the last few years. Thus, there was indication that the growth rate had reached its peak, and that in the future expansion would be at a more moderate rate. For the first time, the value of iron ore minerals exceeded that of any other mineral mined in Canada.

Northwest Territories.—Prospect drilling at the No. 1 deposit of Baffinland Iron Mines, Ltd., indicated that the ore is massive, hard hematite, 68 to 70 percent iron and low in silica and phosphorus. This deposit, therefore, ranks in quality with some of the best in Brazil, India, and Liberia, but there remains the problem of how to mine the ore and get it to market in the 2- or 3-month ice-free shipping season.

British Columbia.—Coast Copper Co., Ltd., a subsidiary of Consolidated Mining & Smelting Co. of Canada, Ltd., made its first shipment of iron ore concentrate to Japan from its Benson Lake plant on Vancouver Island. The shipment weighing 17,000 tons was made in the Japanese ship *San Pedro Maru* through Port McNeil. Texada Mines Ltd. after successfully converting from open-pit to underground operations increased its shipments of iron ore to Japan to more than 500,000 tons compared with the 425,000 tons the company shipped in 1963. Zeballos Iron Mines Ltd., which suspended operations at its four iron deposits on the northwest coast of Vancouver Island in February, resumed operations in early summer and shipped 17,096 tons of iron ore in the Japanese ship *Nitta Maru* on August 6. The Government of British Columbia granted Wesfrob Mines Ltd., a fully-owned subsidiary of Falconbridge Nickel Mines, Ltd., the right to sell 850,000 tons of iron ore concentrate from its new mine on Queen Charlotte Islands to the Mitsubishi Shoji Kaisha of Japan. However, the Government retained the right to half of the concentrate produced, upon 6 months notice.

Newfoundland-Quebec.—The Iron Ore Company of Canada celebrated its first decade as a major iron ore producer. In 10 years the company produced and shipped more than 100 million tons of high-grade direct-shipping ore, and in 1963 began producing high-grade pellets. Wabush Mines concentrator near Wabush Lake in Labrador and its pelletizing ore dock storage and service facilities at Pointe Noire, Que., on the south shore of Sept Iles Bay, were essentially completed by the end of the year.[3]

Ontario.—The Jones & Laughlin Steel Corp. shipped its first carload of finished pellets from its Adams mine, 5 miles south of Kirkland Lake, in northern Ontario. It was reported that the Algoma Steel Corp., Ltd., was considering opening a mine in Goulais range at Cowie Lake 40 miles northeast of Sault Ste. Marie. Preliminary exploration indicated that the property contains more than 150 million tons of low-grade ore. Algoma was considering a concentrating and pelletizing plant at the mine site.

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[3] Northern Miner (Toronto). Big Wabush Mine Now in Tune-Up for Production. V. 50, No. 45, Jan. 28, 1965, pp. 1, 2.

Mexico.—According to a publication of the National Bank of Exterior Commerce of Mexico, Mexico has 92 known iron ore deposits which contain 570 million metric tons of ore averaging 57 percent iron.[4]

A United Nations survey team discovered extensive iron ore deposits which may contain as much as 50 million tons of ore in a region bordering the States of Colima and Michoacan, near Mexico's western coast.

SOUTH AMERICA

Argentina.—Minera Siderurgica Patagonica Sociedad Anonima (MISIPA), an international consortium, announced that it has proved an iron ore reserve of more than 40 million tons in the Sierra Grande iron ore deposits in the Province of Rio Negro.[5]

The Inter-American Development Bank granted MISIPA a $400,000 technical assistance loan to develop the Sierra Grande iron ore deposits.

Brazil.—Companhia Vale do Rio Doce mined over 9 million tons of iron ore and exported almost 8 million tons in 1964. The company embarked on an expansion program to increase its iron ore output to over 20 million tons annually by 1970. Part of the expansion will be financed by a loan of $28.8 million made by the Inter-American Development Bank. The Brazilian Government, whose iron ore export policy has been vague, unequivocally stated the need for rapidly increasing iron ore exports and support for private enterprise on an equal basis with State-owned companies to build their own port facilities and thus approved The Hanna Mining Co.'s plan for a major ore dock at Sepetiba Bay, near Rio de Janeiro.

Chile.—Preliminary exploration of the Boqueron-Chañar iron ore deposit north of Vallenar, by Corporación de comento de la Producción, (CORFO) indicated a deposit of 200 million tons of ore averaging 65 percent iron.[6] The deposit is deep within sedimentary rocks. The iron ore mines agreed to cut prices $1 to $8.90 per ton f.o.b. on ore sold to Japan.

The Chilean Government authorized imports of foreign capital which will permit the Canadian Foreign Ore Development Corporation to import $3 million to develop the Antofagasta, Atacama, and Coquimbo iron ore properties of the Santa Fe Mining Company.

Peru.—Marcona Mining Co. received a credit of $13.8 million from the Export-Import Bank of America to expand the capacity of its agglomerating plant, which was finished in 1963, from the original 1 million tons to 1.25 million tons.

Venezuela.—The Minister of Mines and Hydrocarbons announced on April 1, 1964, that the Government was studying a project proposed by the Orinoco Mining Company to build a reduction plant in the Guayana area to upgrade 60 percent iron ore to 85 percent iron. The plan calls for the construction of a plant at cost of $35 to $40 million which would have an initial capacity of 1 million tons of enriched product. Subsequently, the capacity would be increased to 10 million tons annually, approximately the present iron ore production rate of the Orinoco Mining Company.

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[4] Bureau of Mines. Mineral Trade Notes. V. 60, No. 3, March 1965, pp. 8–9.
[5] Bureau of Mines. Mineral Trade Notes. V. 58, No. 3, March 1964, pp. 14–15.
[6] Bureau of Mines. Mineral Trade Notes. V. 59, No. 5, November 1964, p. 31.

EUROPE

European Coal and Steel Community.—Iron ore production of the six-nation ECSC was slightly more in 1964 than in 1963. However, only France among the six increased production, as European low-grade ore was supplanted by imports of high grade. It was obvious that iron ore mining in West Germany had become increasingly unprofitable.

Bulgaria.—It was reported that about 320 million tons of iron and manganese ores have been discovered to date in Bulgaria. Most of the known iron ores are in the Kremikovtsi deposits in the Balkan Mountains.

France.—Three French iron and steel companies embarked on a project to concentrate and agglomerate the Minette ores of the Lorraine district. The agglomeration plant is to have an annual capacity of 1 million tons.[7]

Italy.—A fluidized bed roasting plant to treat iron pyrites and obtain a 65 percent iron concentrate was installed in the Montecatini, Soc. Generale per l'Industria Mineraria e Chimica, plant at Follonica, Italy.[8]

Norway.—The State-owned Sydvaranger A/S of Oslo, Norway's largest mining company, announced plans to double its iron ore concentrate productive capacity to 3 million tons annually in the immediate future.[9]

Sydvaranger sold its entire 1964 output of iron ore in advance to United Kingdom, West Germany, Austria, and Norway.

Sweden.—The State-owned Luossavaara-Kiirunavaara (LKAB) announced that its newly opened mine at Svappavaara began operating in 1964. LKAB also announced that it was investing in a new uniform sublevel-caving mining system at its mines in the Malmberget area, and that pelletizing facilities at Malmberget will be increased to somewhat more than 1 million tons annually. LKAB's total pelletizing capacity is expected to exceed 3 million tons annually by 1966 and to be further increased to 4 million tons annually in 1968. Output of LKAB's Malmberget mine was inadvertently omitted from production reported in the 1963 Minerals Yearbook. LKAB produced 7.3 million tons of iron ore in 1963, 13.1 from the Kiruna mines, and 4.2 from the Malmberget mines, 1964 production totaled 19.7 million tons, 15.1 million from Kiruna and 4.6 million from Malmberget.

The Grängesberg Co.'s ore carrier *Avidjaur* loading 12,500 tons of high-grade ore from the Malmberget mines inaugurated the new iron ore shipping port near Lulea, on Svartön near Lulea, Sweden. The new port has capacity for storing 5 million tons of iron ore and loading facilities to move 9 to 12 million tons annually, at a rate of 8,000 tons per hour. The dock can accommodate 35,000-ton-capacity ore carriers.

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[7] Mining Journal (London). Enrichment of French Iron Ore. V. 262, No. 6714, Apr. 24, 1964, pp. 320–321.

[8] Industrial and Engineering Chemistry. V. 56, No. 11, November 1964, p. 7.

[9] Bureau of Mines. Mineral Trade Notes. V. 60, No. 2, February 1965, p. 20.

ASIA

India.—India's Minerals and Metals Trading Corporation contracted with Czechoslovakia, Rumania, Poland, Hungary, East Germany, and Yugoslavia for sale of iron ore. The Corporation also sold iron ore to Holland, Belgium, and Greece. The first shipment of ore from the Government-owned Kiriburu mines in Orissa was made through the port of Visakhapatnam, on April 22, 1964. The National Minerals Development Corporation was developing iron ore deposits at Bailadila hills of Madhya Pradesh and considering establishing a pelletizing plant there. Japanese steel companies agreed to purchase 4 million tons of ore per year, for 19 years, beginning in 1966 from the Bailadila deposits.

Japan.—Tokai Iron & Steel Co., Ltd., a subsidiary of the Fuji Iron and Steel Co., Ltd., lit a new 3,500 ton per day blast furnace on September 5 at its plant near Nagoya City. The new furnace is among the world's largest with a working volume of 71,114 cubic feet and a hearth diameter of 32.15 feet. It has two bells for high-top-pressure operation, and two tap holes to facilitate cleaning and repairing the iron runners.

The Japanese iron and steel industry apparently found that pellets are the preferred raw material for its blast furnaces, as it increased its own pelletizing capacity and contracted to buy more iron ore pellets from foreign sources.

Philippines.—Philippine Iron Ore Mines, Inc., completed financial arrangements to install iron ore concentrating equipment with capacity of 700,000 to 800,000 tons annually, and a pelletizing plant with capacity of 750,000 tons of 65 percent iron pellets.[10] Atlas Consolidated Mining & Development Corp. negotiated with Kawasaki Steel Corp., of Japan for a loan to build a pelletizing plant to treat its byproduct magnetite concentrate.

AFRICA

Algeria.—The Algerian Government made a determined effort to enlarge the market for its iron ore. The resulting market diversification and increasing activity in European steel mills enabled Algeria to increase its iron ore production in 1964 to more than 2.7 million tons, equal the average output of the past 20 years.

Angola.—An iron ore deposit of undetermined size was discovered by the Lobito Mineral Co. in the area of Macedo de Cavaleires (Andulo), District of Bie. Approximately 1,800 tons of iron ore per day produced by Companhia do Manganes de Angola, at Quitota, was transported daily to the port of Luanda by the Luanda railway.[11]

It was reported that Portuguese, West German, and American commercial interests are financing development of an iron ore deposit at Cossinga, about 80 miles north of the South West African border.

United Arab Republic (Egypt).—The Ministry of Industry conducted a study of iron ore deposits in the Ghorabi Hills of the Baharyia Oasis and determined that the area contains indicated reserves of 100 to 250 million tons of hematite, averaging 47.9 percent iron, and 100 million tons of low-grade ore averaging 38.2 percent iron.[12] The United Arab Republic planned to exploit the deposits to satisfy its need for iron and steel, estimated to reach 2.5 million tons annually by the end of its second 5-year plan, 1965–70.

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[10] Bureau of Mines. Mineral Trade Notes. V. 59, No. 3, September 1964, pp. 28–30.
[11] Bureau of Mines. Mineral Trade Notes. V. 58, No. 6, June 1964, p. 15.

Gabon.—Studies of the feasibility of a transportation system in connection with exploitation of the Makambo iron ore deposits continued throughout the year.

Liberia.—Liberian-American-Swedish Minerals Co. (LAMCO) which started iron ore production in 1963 produced 7,230,000 tons of ore in 1964. The company shipped 6,875,000 tons of ore through lower Buchanan, destined as follows: West Germany, 2,683,000; United States, 2,661,000; Belgium, 826,000; France, 359,000; Italy, 274,000; Sweden, 58,000; and United Kingdom, 14,000. Shipments averaged 67 percent iron, dry.

Mauritania.—In its full year of production Societe Anonyme des Mines de Fer de Mauritanie (MIFERMA) shipped about 5 million tons of iron ore from Port-Etienne. The company installed a plant at the port to screen 1,200 tons of iron ore per hour, and plans to install additional equipment with an annual capacity of 5.5 million tons in 1965, and 6 million tons by 1966. MIFERMA contracted with Cockerill-Ougrée, a Belgium steel company, to supply 500,000 tons of 65.5 percent iron ore annually starting early in 1965.

Mozambique.—It was reported that private companies in West Germany, Japan, the United Kingdom, and the United States were interested in iron ore deposits near Namapa in the Mozambique district. The ore reportedly contains 93 percent iron oxide, 0.2 percent titanium, 1 percent columbite, 0.9 percent tantalite, and 1.5 percent tin.[13]

Sierra Leone.—The British-owned Sierra Leone Development Company (DELCO) completed a $25 million expansion of its Sierra Leone iron-ore mine. New facilities include an ore-loading pier, new track on its 52-mile railroad, new rolling stock, power shovels, and a concentrating plant. The new facilities will increase mine capacity 40 percent to 2.8 million tons of 64 percent iron ore annually.

Swaziland.—The Ngwenya iron mine owned by Swaziland Iron Ore Development Company, Ltd., and the new railway line from the mine to the Mozambique border were officially opened on November 5, 1964. The first iron ore exported from the mine was carried in the world's largest ore carrier the 77,500-ton-capacity *Inayama* from the newly constructed ore-loading facilities at Lourenco Marques. Although the *Inayama* carried the first cargo in fulfilling the company's 12-million ton, 10-year contract with the Yawata Iron and Steel Co., Ltd., and Fuji Iron and Steel Company of Japan, the Lourenco Marques' facilities were given a trial run earlier when 27,000 tons of ore was loaded into the Norwegian-owned ship *Arica*.

OCEANIA

Australia.—An iron ore industry in Western Australia developed very rapidly as four companies announced firm contracts to sell Japanese steel mills 175 million tons of iron ore within the next 22 years.

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[12] Bureau of Mines. Mineral Trade Notes. V. 59, No. 3, September 1964, p. 30.
[13] Bureau of Mines. Mineral Trade Notes. V. 58, No. 6, June 1964, p. 16.

Deliveries are to start in 1966, 1967, and 1969. The contracts extend through 7, 8, 15, and 22 years. If the ore is delivered at a uniform rate over the length of existing contracts between Australian iron ore producers and Japanese consumers, deliveries will exceed 12 million tons annually by 1970.

In addition to the foregoing developments, the Australian Government approved an agreement with the Basic Materials Pty., Ltd., a wholly owned subsidiary of Cleveland-Cliffs Iron Co., to develop iron ore deposits in the Robe River area of northwestern Australia. Subject to winning contracts for sale of pellets, the company is to establish a 3-million-ton-per-year pelletizing plant. Pickands Mather & Co. of Cleveland, Ohio, and Mitsubishi Shoji Kaisha Ltd., Tokyo, Japan, agreed to explore iron ore deposits at Savage River in the island state of Tasmania. If the preliminary investigations prove that the deposits can be exploited profitably, the companies plan to install facilities to produce a minimum of 2 million tons of high-grade iron ore pellets per year.

TECHNOLOGY

Geophysical methods were used increasingly in prospecting for iron ore. The iron deposits sought today are characteristically large and massive and therefore readily susceptible to discovery by geophysical prospecting. Pan American Petroleum Corp., discovered deposits with an estimated 3.5 billion tons of material containing 500 million tons of recoverable iron, using an airborne magnetometer. Following aeromagnetic surveys of southeast Minnesota covering the mid-continent gravity anomaly, geologists concluded that iron formation of possible value may exist in the area. A hidden iron ore body, 3 miles west of Rison, Ark., first disclosed as a magnetic anomaly, was proved by drilling.

The Office of Minerals Exploration of the Department of the Interior contracted with Bonanza Gold, Inc., of Spokane, Wash., to explore for iron ore in the Jumbo Basin on Prince of Wales Island, Alaska.

Papers describing the development of magnetite in the iron formation of the Lake Superior district and a study of the origin of Precambrian iron formations gave better understanding of the nature of iron ores.[14] Evidence was presented that the magnetite in the iron formations of the Lake Superior region were formed under conditions of low-grade regional metamorphism by oxidation of the primary ferrous-iron minerals, siderite and greenalite. A model was proposed to explain the origin of the iron formations of Lake Superior type based on the absence or marked deficiency of free oxygen in the atmosphere.

Metallurgical researchers emphasized flotation studies, while practicing metallurgists were more interested in autogenous grinding, pelletizing, and benefication plant automation. Most of the flotation research, which will be described later, was done in Bureau of Mines laboratories. Metallurgists at the University of Wisconsin found that quartz flotation could be entirely suppressed in the presence of activating ions by chelation during complete flotation of hematite.[15] Vacuum flotation tests showed that the acid limiting edge of the flotation area for a Brazilian hematite in the presence of dodecylamine is a straight line of slope approximately unity.[16]

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[14] LaBerge, Gene L. Development of Magnetite in Iron-Formations of the Lake Superior Region. Econ. Geol., v. 59, No. 7, November 1964, pp. 1313–1342.
Lepp, Henry, and Samuel S. Goldrich. Origin of Precambrian Iron Formations. Econ. Geol., v. 59, No. 6, September–October, 1964, pp. 1025–1060.

The Research and Development Division of Head Wrightson and Co. Ltd., Thornaby-on-Tees, developed experimental pellet testing equipment, that, when used with a suitable recorder enabled materials in pellet form to be compressed in a reproducible manner with strength and deformation conditions accurately and conveniently recorded.[17]

Metallurgists at the Research Council of Alberta described a hydrometallurgical process for extracting iron from low-grade ores.[18] The process consists of roasting ore with coal, treating the roasted material with hydrochloric acid, filtering to remove the insoluble residue, and then evaporating the solution to form hydrated ferrous-chloride crystals, which are dried and reduced to iron powder in a hydrogen atmosphere. Hydrogen and hydrogen-chloride are recovered and recycled in the system. In other hydrometallurgical studies, researchers at the University of Tokyo in Japan described the kinetics of the dissolution of ferric oxides in hydrochloric acid (HCl), sulfuric acid (H_2SO_4), bromic acid (HBr), nitric acid (HNO_3), phosphoric acid (H_3PO_4), and perchloric acid ($HClO_4$).[19]

Scientists continue to develop the kinetics of reducing iron ore with various reductants under differing physical conditions.[20] Although iron oxide reduction kinetic data are not yet complete for all the possible combinations of variables in a blast furnace, most researchers oriented their studies to direct reduction processes.

The Montecatini Company announced that its fluid bed ore roasting process at its plant at Follonica, Italy, which processes iron pyrite to obtain sulphuric acid and high-grade, 65-percent iron pellets is a commercial success. The process was developed over several years of cooperative research by Montecatini of Milan, Italy, and Dorr-Oliver Inc., of Stamford, Conn.

There was an apparent revival of interest in direct reduction research after several years of quiet, as Swedish metallurgists described the reduction of fine ore to pig iron in a rotating furnace using oxygen and a carbonaceous reducing agent with an appropriate flux,[21] and Imperial Oil Ltd., a Canadian affiliate of the Standard Oil Co. of New

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[15] Daellenbach, Charles B., and Theodore D. Tiemann. Chelation of Quartz Activating Ions in Oleic Acid Flotation. Trans. Soc. Min. Eng., v. 229, No. 1, March 1964, pp. 59–64.

[16] Joy, A. S., D. Watson and R. W. G. Cropton. Collector Adsorption and Surface Charge Density. Trans. Soc. Min. Eng., v. 229, No. 1, March 1964, pp. 5–7.

[17] Metal Industry (London). Testing Pellets of Iron Ore. V. 104, No. 22, May 28, 1964, p. 728.

[18] Gravenor, C. P., G. J. Govett, and T. Rigg. A Hydrometallurgical Process for the Extraction of Iron from Low-Grade Ores. Canadian Min. and Metal. Bull. (Montreal, Canada), April 1964, pp. 421–428.

[19] Azuma, Kiyoshi, and Hiroshi Kametani. Kinetics of Dissolution of Ferric Oxide. Trans. Met. Soc. AIME, v. 230, No. 4, June 1964, pp. 853–862.

[20] Feinman, Jerome. Kinetics of Hydrogen Reduction of Iron Ore in a Batch-Fluidized Bed. Ind. and Eng. Chem. Process Design and Development, v. 3, No. 3, July 1964, p. 241–247.

Grieveson, P., and E. T. Turkdogan. Kinetics of Oxidation and Reduction of Molten Iron Oxide. Trans. Met. Soc. AIME, v. 230, No. 7, December 1964, pp. 1609–1614.

Seth, B. B. L., and H. U. Ross. The Mechanism of Iron Oxide Reduction. Trans. Met. Soc. AIME, v. 233, No. 1, January 1965, pp. 180–185.

[21] Bengtsson, E., K. Almquist, and A. Josefsson. Ironmaking in the Stora Rotary Furnace. J. Metals, v. 16, No. 4, April 1964, pp. 337–339.

Jersey, entered a multimillion-dollar research program to investigate the direct reduction of iron ore using petroleum products.

Metallurgists seeking to improve blast furnace performance experimented with high top pressure, increased wind rates and hot blast temperature, and refinements in injecting fuel in the smelting zone. Smelting tests using partially reduced ores demonstrated that their use could increase productivity and cut down on fuel requirements. Japanese metallurgists described computer control of a blast furnace to obtain optimum raw-material blending ratios, wind rate, and hot blast temperatures.[22] The new blast furnaces built in the United States were equipped with completely automated charging systems.

Bureau of Mines Research.—Bureau field engineers continued their examination of iron ore deposits in Washington, Oregon, and California. Fieldwork in Montana, Idaho, Arizona, and South Dakota, and cooperative projects to investigate brown iron ore resources with the States of Alabama and Georgia were completed. Reports describing cooperative work on the brown ores were prepared. A report describing the reconnaissance of iron resources of Arizona was published, and an engineering-economic report on the iron ore studies in South Dakota was completed by the end of the year, but was not fully processed for publication.

Iron ore beneficiation studies were continued at the Bureau's Minneapolis and Tuscaloosa Metallurgy Research Centers. Researchers at Tuscaloosa devised methods for improving recovery of brown iron ore washing plants in the Southern district. They continued their investigation to improve methods for treating the calcareous hematitic ores, but were unsuccessful in developing a commercial process. Flotation has been the principal element in the Bureau's beneficiation studies at Minneapolis, and these are supported by extensive fundamental research into the nature of iron mineral occurrence. A fundamental research report describing the occurrence of properties of iron phyllosilicate minerals in the low-grade metamorphic iron formations of the Lake Superior region was published.[23]

Flotation research in Minneapolis covered treatment of a wide range of ore types, but the reports published in 1964 dealt with the low-grade hematitic goethic jaspers of the Marquette Range in Michigan.[24]

Bureau of Mines metallurgists demonstrated in laboratory-scale experiments that good recovery of iron could be made by roasting Mesabi ores with solid reductants and then separating the iron minerals from the gangue magnetically.[25] They found that lignite and lignite chars gave the best results. Exploiting their laboratory findings they used lignite and lignite anthracite mixtures simultaneously to prereduce and indurate iron ore pellets in a 3- by 36-foot rotary kiln. The pellets were smelted in the Bureau's experimental blast furnace at Bruceton, Pa., where it was found that their use resulted in a substantial decrease in coke rates and higher production compared with smelting conventional unreduced pellets.[26]

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[22] Shibuya, Jutaro. Computer Control of Blast Furnace. Iron and Steel Eng., v. 41, No. 2, February 1964, pp. 81–86.

[23] Blake, Rolland L. Some Iron Phyllosilicates of the Cuyuna and Mesabi Districts in Minnesota. BuMines Rept. of Inv. 6394, 1964, 33 pp.

[24] Frommer, D. W. USBM Tests on Selective Iron Ore Flotation Point Way to Greater Recoveries. Min. Eng., v. 16, No. 4, April 1964, pp. 67–71, 80.

Sorensen, R. T., A. F. Colombo, and D. W. Frommer. Flotation Treatment of Experimental Iron Ore Tailing From Champion Mine, Marquette Range, Michigan. BuMines Rept. of Inv. 6532, 1964, 13 pp.

[25] Wasson, P. A., and M. M. Fine. Experimental Conversion of Hematite to Magnetite With Solid Reductants. BuMines Rept. of Inv. 6338, 1963, 13 pp.

The Bureau's experimental blast furnace was redesigned and completely rebuilt to operate at pressures of up to 55 pounds per square inch. It was dedicated on April 21, and operated the remainder of the year to establish base wind rates, the effect of prereduced ore and pellets on coke and production rates, and to develop a sophisticated probing system for obtaining data inside the furnace shaft. Smelting prereduced pellets produced in Canada by the S-L process confirmed the tests made on the Bureau's prereduced pellets which were reported in Report of Investigation 6523.[27]

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[26] Fine, M. M., P. L. Woolf, and N. Bernstein. Experimental Production and Smelting of Prereduced Iron Ore Pellets. BuMines Rept. of Inv. 6523, 1964, 28 pp.

[27] Work cited in footnote 26.

Iron and Steel

By Robert A. Whitman[1]

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A RECORD steel ingot production in 1964 of 127 million tons was led by a phenomenal increase of 80 percent in steel made in basic oxygen converters. Pig iron production increased 19 percent, and shipments of steel products increased 12 percent. During the first 6 months the gain over that of 1963, though modest, seemed based solidly on demand, but talk of inventory buildup raised third quarter production nearly 7 million tons over that of the same quarter in 1963. Record fourth quarter production was caused by purchasing for expanded inventory which resulted from rumors that there would be a steel strike.

The steel industry received notice that a request for negotiations for a new labor contract would be formally tendered January 1, 1965.

TABLE 1.—Salient iron and steel statistics

(Thousand short tons)

	1955-59 (average)	1960	1961	1962	1963	1964
United States:						
Pig iron:						
Production	69,530	66,501	64,853	65,638	71,840	85,458
Shipments	69,492	65,612	65,307	65,727	72,211	85,693
Imports for consumption	349	331	377	500	645	736
Exports	260	112	416	154	70	176
Steel:[1]						
Production of ingots and castings (all grades):						
Carbon	95,640	90,862	89,338	89,160	98,714	114,442
Stainless	1,110	1,004	1,137	1,085	1,204	1,443
All other alloy	7,984	7,416	7,539	8,083	9,343	11,191
Total	104,734	99,282	98,014	98,328	109,261	127,076
Index (1955-59=100)	100.0	94.8	93.6	93.9	104.3	121.3
Total shipments of steel mill products	75,431	71,149	66,126	70,552	75,555	84,945
Imports of major iron and steel products[2] [3]	2,056	3,570	3,308	4,297	5,637	6,628
Exports of major iron and steel products	4,061	3,247	2,221	2,266	2,670	3,911
World production:						
Pig iron[4]	226,283	285,355	282,540	292,542	310,121	350,092
Steel ingots and castings	313,590	381,590	386,900	396,300	425,470	480,780

[1] American Iron and Steel Institute.
[2] Data not comparable for all years.
[3] Bureau of the Census.
[4] Includes ferroalloys.

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[1] Commodity specialist, Division of Minerals.

The steel industry paid $4,376 million in wages and salaries in 1964. The net billing value of products shipped was $16,200 million compared with $14,500 million in 1963.

Trends and Developments.—The $1,600 million capital investment by the steel industry was primarily for plant modernization to increase productivity and reduce cost. The emphasis in spending was for new basic oxygen converters, for rebuilding blast furnaces to increase productivity, and for continuous casting machines, with the automatic controls that these accelerated steelmaking methods demand.

PRODUCTION AND SHIPMENTS OF PIG IRON

A new record-high pig iron production in 1964 increased 19 percent over that of 1963. The average production of pig iron per blast furnace day was 1,443 short tons, according to the American Iron and Steel Institute (AISI). Pennsylvania, Ohio, and Indiana produced over half the pig iron.

One blast furnace was dismantled and four were abandoned, leaving a total of five fewer at the end of the year. However, 44 more blast furnaces were in operation at the end of 1964 than in 1963.

Metalliferous Materials Consumed in Blast Furnaces.—The record steel ingot production resulted in record amounts of materials being consumed in blast furnaces, but the significant increases were in domestic iron ore, agglomerates, and scrap. The average of 108 pounds of scrap per ton of pig iron produced was the highest for the last 10 years. The combined net charge of metalliferous materials per ton of pig iron produced decreased 42 pounds per ton. The amount of flux consumed per ton of pig iron increased 14 pounds, reversing a 10-year trend. This was a result of the acceleration of ironmaking in the blast furnace.

There was 5.1 million tons of foreign agglomerates used in blast furnaces in 1964, which was four times the quantity used in 1963. Blast furnace charge included 41.1 million tons of sinter, 13.8 million tons of self-fluxing sinter, 24.6 million tons of pellets, and 1.6 million tons of unclassified agglomerates. The use of only 10,000 tons of nodules, none self-fluxing, was reported.

TABLE 2.—Pig iron produced and shipped in the United States, by States

(Thousand short tons and thousand dollars)

State	Produced		Shipped from furnaces			
	1963	1964	1963		1964	
	Quantity		Quantity	Value	Quantity	Value
Alabama	3,908	4,321	3,899	$217,020	4,353	$234,346
Illinois	4,476	5,671	4,541	261,186	5,579	322,098
Indiana	9,957	11,511	10,050	564,355	11,483	658,162
Ohio	12,734	15,163	12,772	737,990	15,355	925,078
Pennsylvania	17,290	20,986	17,338	1,028,796	21,005	1,207,869
California, Colorado, Utah	4,044	4,726	4,062	204,378	4,739	276,743
Kentucky, Maryland, Tennessee, Texas, West Virginia	8,707	10,582	8,720	557,866	10,641	636,785
Michigan and Minnesota	6,451	7,387	6,523	360,659	7,405	409,657
New York	4,273	5,111	4,306	290,218	5,133	320,568
Total	71,840	85,458	72,211	4,222,468	85,693	4,991,306

Canada, Venezuela, and Chile furnished 87 percent of the foreign iron ore consumed by blast furnaces in the United States.

According to the AISI, blast furnace consumption of oxygen decreased 0.6 billion cubic feet in 1964 to 9.7 billion cubic feet. Blast furnaces consumed 40.5 billion cubic feet of natural gas, 3.4 billion cubic feet of coke-oven gas, and 46.6 million gallons of oil, according to data collected by the Bureau of Mines. There were 13,650 tons of bituminous and anthracite coal used in blast furnaces during 1964.

TABLE 3.—Foreign iron ore and manganiferous iron ore consumed in manufacturing pig iron in the United States, by sources of ore

(Short tons)

Source	1963	1964[1]	Source	1963	1964[1]
Brazil	48,229	188,745	Venezuela	4,749,444	5,779,531
Canada	5,829,190	4,658,880	Other countries	526,359	1,148,522
Chile	1,220,384	1,169,654			
Peru	191,282	354,326	Total	12,564,888	13,299,658

[1] Excludes 24.5 million tons used in making agglomerates.

TABLE 4.—Pig iron shipped from blast furnaces in the United States, by grades[1]

(Thousand short tons and thousand dollars)

Grade	1963			1964		
	Quantity	Value		Quantity	Value	
		Total	Average per ton		Total	Average per ton
Foundry	1,657	$92,156	$55.62	1,761	$95,984	$54.51
Basic	65,062	3,803,535	58.46	78,003	4,546.819	58.29
Bessemer	2,821	171,317	60.73	2,789	165,308	59.27
Low-phosphorus	173	10,554	61.01	325	19,436	59.80
Malleable	2,299	135,070	58.75	2,523	146,810	58.19
All other (not ferroalloys)	199	9,836	49.43	292	16,949	58.04
Total	72,211	4,222,468	58.47	85,693	4,991,306	58.25

[1] Includes pig iron transferred directly to steel furnaces at same site.

TABLE 5.—Number of blast furnaces (including ferroalloy blast furnaces) in the United States, by States

State	Jan. 1, 1964			Jan. 1, 1965		
	In blast	Out of blast	Total	In blast	Out of blast	Total
Alabama	11	10	21	16	3	19
California	3	1	4	4	----------	4
Colorado	3	1	4	3	1	4
Illinois	9	13	22	16	6	22
Indiana	21	2	23	21	2	23
Kentucky	2	1	3	2	1	3
Maryland	6	4	10	10	----------	10
Michigan	9	----------	9	9	----------	9
Minnesota	1	1	2	2	----------	2
New York	10	7	17	12	3	15
Ohio	27	22	49	36	13	49
Pennsylvania	37	27	64	50	13	63
Tennessee	1	2	3	----------	3	3
Texas	2	----------	2	2	----------	2
Utah	2	3	5	3	2	5
Virginia	----------	2	2	1	1	2
West Virginia	3	1	4	4	----------	4
Total	147	97	244	191	48	239

Source: American Iron and Steel Institute.

TABLE 6.—Iron ore and other metallic materials, coke and fluxes consumed and pig iron produced in the United States, by States

(Short tons)

Year and State	Metalliferous materials consumed							Net coke	Fluxes	Pig iron produced	Metalliferous materials consumed per ton of pig iron made				Coke and fluxes consumed per ton of pig iron	
	Iron and manganiferous ores		Agglomerates	Net ores and agglomerates [1]	Net scrap [2]	Miscellaneous [3]	Net total				Net ores and agglomerates [1]	Net scrap [2]	Miscellaneous [3]	Total	Net coke	Fluxes
	Domestic	Foreign														
1963:																
Alabama	2,872,047	[r]1,129,847	3,139,514	6,967,701	119,372	113.974	7,201,047	3,240,051	1,055,212	3,907,537	1.783	0.031	0.029	1.843	0.829	0.270
Illinois	3,167,151	(4)	4,249,190	7,222.567	320,492	471,620	8,014,679	3,271.955	819,839	4,476,337	1.614	.072	.105	1.791	.731	.183
Indiana	6,095,289	1,829,021	9,432,431	16,632,897	225,326	1,529,729	18,387,952	6,581,129	1,436,894	9,957,082	1.670	.023	.154	1.847	.661	.144
Ohio	5,119,029	2,007,183	12,226,113	18,558,176	1,074,130	1,472,743	21,105,049	8,852,586	2,926,796	12,733,837	1.458	.084	.116	1.658	.695	.230
Pennsylvania	5,424,093	2,848,667	17,761,693	25,335,965	961,519	2,004,602	28,302,086	11,259,322	2,598,801	17,289,805	1.465	.056	.116	1.637	.651	.150
California, Colorado, Utah	(4)	(4)	4,249,452	6,857,560	139,988	131,051	7,128,599	2,387,376	703,462	4,044,051	1.696	.035	.032	1.763	.590	.174
Kentucky, Tennessee, Texas	1,059,349	353,062	1,751,297	3,119,595	60,720	126,691	3.307,006	1,182,501	475,416	1,759,012	1.773	.035	.072	1.880	.672	.270
Maryland and West Virginia	(4)	(4)	6,732,922	10,433,717	187,988	599,636	11,221,341	4.446,682	676,751	6,947,446	1.502	.027	.086	1.615	.640	.097
Michigan and Minnesota	(4)	(4)	7,663,773	10,032,859	258,528	307,979	10,599,366	4,094,351	1,433,738	6,451,261	1.555	.040	.048	1.643	.635	.222
New York	1,647,015	280,503	4,929,479	6,618,290	116,476	378,603	7,113.369	2,845,734	1,087,396	4,273,375	1.549	.027	.089	1.665	.666	.254
Total	30,938,796	12,564,888	72,135,864	111,779,327	3,464,539	7,136,628	122,380,494	48,161,687	[5]13,214,305	71,839,743	1.556	.048	.099	1.703	.670	.184

1964:																
Alabama	2, 484, 443	1, 548, 083	3. 594, 910	7, 422, 462	111, 397	55, 286	7, 589, 145	3, 649, 460	1, 079, 896	4. 320, 973	1. 718	. 026	. 013	1. 756	. 845	. 250
Illinois	4, 236, 471	(4)	5, 220, 224	9, 022, 912	345, 039	514, 480	9, 882, 431	3, 983, 486	1, 258, 201	5, 671, 009	1. 591	. 061	. 091	1. 743	. 702	. 222
Indiana	6, 555. 950	1, 156 253	11, 523, 887	18, 205, 533	207, 269	1, 488, 275	19, 901, 077	7, 339, 461	1, 638, 002	11, 511, 028	1. 582	. 018	. 129	1. 729	. 638	. 142
Ohio	6, 159, 946	1, 753, 649	14, 673, 231	21, 713, 499	1, 320, 517	1, 704, 666	24, 738, 682	9, 977, 842	3, 654, 148	15, 163, 176	1. 432	. 087	. 112	1. 632	. 658	. 241
Pennsylvania	7, 857, 245	4, 048, 268	19, 781, 888	30, 825, 959	1. 059, 531	2, 423, 251	34, 308, 741	13, 455, 012	3, 585, 231	20. 986, 345	1. 469	. 050	. 115	1. 635	. 641	. 171
California, Colorado, Utah	(4)	(4)	4, 636. 842	8, 009, 805	991, 490	149, 258	9, 150, 553	2, 755, 970	811, 013	4, 726, 261	1. 695	. 210	. 032	1. 936	. 583	. 172
Kentucky, Maryland, Tennessee, Texas, West Virginia	1, 962, 501	3, 897, 716	11, 184, 176	16, 413, 990	278, 158	1, 019, 137	17, 711, 285	6, 796, 458	1, 511, 766	10, 581 928	1. 551	. 026	. 096	1. 674	. 642	. 143
Michigan and Minnesota	(4)	(4)	9, 653, 049	11. 576, 902	183, 691	348, 503	12, 109, 096	4, 573, 939	1, 479, 034	7, 386, 353	1. 567	. 025	. 047	1. 639	. 619	. 200
New York	1, 464, 287	645, 529	5. 897, 949	7, 767, 468	133, 326	464, 018	8, 364, 812	3, 250, 092	1, 334, 387	5, 111, 326	1. 520	. 026	. 091	1. 636	. 636	. 261
Total	36, 218, 021	13, 299, 658	86, 166, 156	130, 958, 530	4, 630, 418	8, 166. 874	143, 755. 822	55, 781, 720	[6] 16, 351, 678	85, 458, 399	1. 532	. 054	. 096	1. 682	. 653	. 191

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[r] Revised.

[1] Net ores and agglomerates equal ores plus agglomerates plus flue dust used minus flue dust recovered.

[2] Excludes home scrap produced at blast furnaces.

[3] Does not include recycled material.

[4] Included in total.

[5] Fluxes consisted of 9,066,274 tons of limestone and 4,148,031 tons of dolomite, excluding 4,686,330 tons of limestone and 1,913,125 tons of dolomite used in agglomerate production at or near steel plants and an unknown quantity used in making agglomerates at mines.

[6] Fluxes consisted of 10,743,800 tons of limestone and 5,607,878 tons of dolomite, excluding 4,876,636 tons of limestone and 1,820,229 tons of dolomite used in agglomerate production at or near steel plants and an unknown quantity used in making agglomerates at mines.

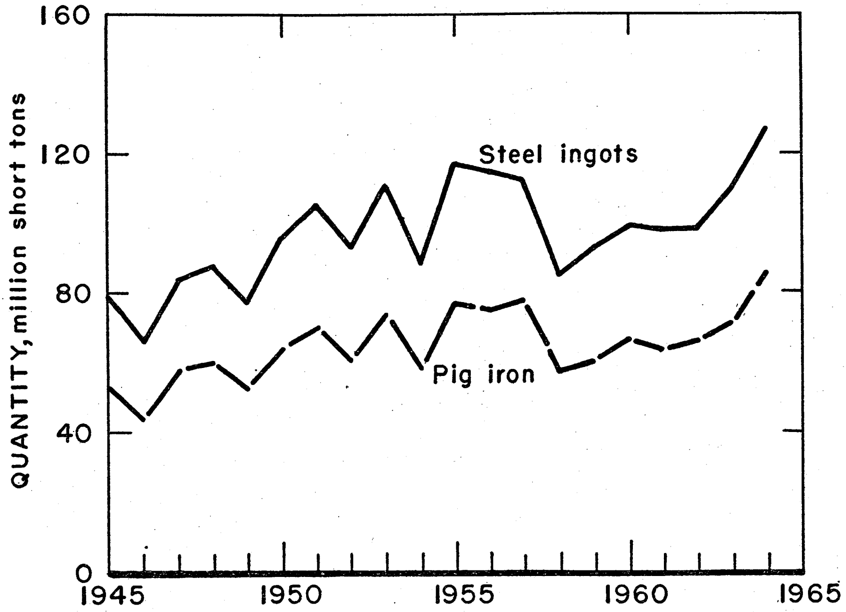

FIGURE 1.—Trends in production of pig iron and steel ingots in the United States.

PRODUCTION AND SHIPMENTS OF STEEL

Record-high production and shipments of steel ingots and steel products were made in 1964. The industry produced 127 million short tons of ingots, 16 percent more than in 1963, and nearly 9 percent better than the previous record of 117 million tons in 1955. Production of steel in basic oxygen converters nearly doubled to furnish 12 percent of the total steel ingot produced. Open-hearth furnace production dropped to 77 percent, electric furnaces produced 10 percent, and Bessemer converters 0.7 percent. Seventy percent of the steel was made in Pennsylvania, Ohio, Indiana, Illinois, and Michigan. These States produced 24 percent, 17 percent, 14 percent, 8 percent, and 7 percent, respectively.

Total shipments of steel products increased over 9 million tons compared with shipments in 1963. The increase was in all market classifications. Three of the largest consuming groups, construction, automotive, and containers, while taking more steel than in 1963, lost small percentages of their share of the market.

Alloy Steel.[2]—The production of 11.2 million tons of alloy steel (including nearly 62,000 tons for castings but excluding all stainless) was 20 percent greater than that in 1963. Stainless production (including 1,772 tons of direct castings) increased 20 percent to 1.4 million tons. Alloy and stainless represented 10 percent of total production.

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[2] The Bureau of Mines uses the American Iron and Steel Institute specifications for alloy steels, which include stainless and any other steel containing one or more of the following elements in the designated percentages: Manganese in excess of 1.65 percent, silicon in excess of 0.60 percent, and copper in excess of 0.60 percent. The specifications also include steel containing the following elements in any quantity specified or known to have been added to obtain a desired alloying effect: Aluminum, boron, chromium, cobalt, columbium, molybdenum, nickel, titanium, tungsten, vanadium, zirconium, and other alloying elements.

Stainless steel includes all grades of steel that contain 10 percent or more of chromium with or without other alloys or a minimum combined content of 18 percent of chromium with other alloys. Valve or bearing steels, high-temperature alloys, or electrical grades with analyses meeting the definition for stainless steels are included. All tool-steel grades are excluded.

Heat-resisting steel includes all steel containing 4 percent or more but less than 10 percent of chromium (excluding tool-steel grades).

Austenitic (AISI 200 and 300) stainless steel production increased 24 percent to comprise 70 percent of the total stainless production. Series 400 stainless steels increased 7 percent to a volume of 307,000 tons, 2,000 tons more than that in 1962. Production of AISI type 500 and all other high-chromium heat-resisting steels again declined.

The production of alloy and stainless steel in basic oxygen converters rose to 3 percent of the total. Open-hearth furnaces accounted for 58 percent of this production and electric for 39 percent.

Materials Used in Steelmaking.—Pig iron made up 55 percent of the 143.3 million tons of metallics consumed in steelmaking in 1964. According to AISI, 294,690 tons of fluorspar, 5,746,115 tons of limestone, 2,421,723 tons of lime, and 481,739 tons of other fluxes were used in steelmaking. There was 90.6 billion cubic feet of oxygen used in steelmaking, or 30 percent more than that consumed in 1963. Sixty-four percent of the oxygen was used in the open-hearth and 33 percent in basic oxygen converters.

TABLE 7.—Steel production in the United States, by type of furnace[1]

(Thousand short tons)

Year	Open hearth		Bessemer	Basic oxygen process	Electric[2]	Total
	Basic	Acid				
1955–59 (average)	92,946	536	2,360	[3] 861	8,031	104,734
1960	85,964	404	1,189	3,346	8,379	99,282
1961	84,108	394	881	3,967	8,664	98,014
1962	82,578	379	805	5,553	9,013	98,328
1963	88,437	397	963	8,544	10,920	109,261
1964	97,655	443	858	15,442	12,678	127,076

[1] Includes only that steel for castings produced in foundries operated by companies manufacturing steel ingots. Omits about 2 percent of total steel production.

[2] Includes crucible, oxygen converter steel, 1955.

[3] Data for 4-year period only.

Source: American Iron and Steel Institute.

CONSUMPTION OF PIG IRON

Domestic consumption of pig iron increased 19 percent in 1964. The East North Central and Middle Atlantic States consumed over 76 percent of the total production.

TABLE 8.—Metalliferous materials consumed in steel furnaces in the United States

(Thousand short tons)

Year	Iron ore		Agglomerates [1]	Pig iron	Ferroalloys [2]	Iron and steel scrap
	Domestic	Foreign				
1955–59 (average)	2,674	4,986	1,485	61,832	1,455	54,727
1960	1,570	6,251	931	60,092	1,395	51,140
1961	1,913	5,277	855	59,418	1,367	49,455
1962	1,875	4,768	[3] 644	60,561	1,408	49,606
1963	1,783	3,995	[4] 885	66,188	1,557	56,506
1964	2,114	4,816	[5] 1,379	78,925	1,819	64,348

[1] Includes consumption of pig iron and scrap by ingot producers and iron and steel foundries.

[2] Includes ferromanganese, spiegeleisen, silicomanganese, manganese briquets, manganese metal, ferrosilicon, ferrochromium alloys, and ferromolybdenum.

[3] Includes 20,039 tons of sinter, 342,466 tons of pellets, 276,632 tons of nodules, 702 tons of briquets, 3,661 tons of other agglomerates. (532,031 tons of foreign origin.) 1959–62 see Iron and Steel chapter, Minerals Yearbook, v. I, p. 695.

[4] Includes 71,116 tons of sinter, 487,886 tons of pellets, 300,411 tons of nodules, and 25,189 tons of other agglomerates. (875,573 tons of foreign origin.)

[5] Includes 725,575 tons of sinter, 346,390 tons of pellets, 292,938 tons of nodules, and 13,768 tons of other agglomerates. (620,917 tons of foreign origin.)

TABLE 9.—Consumption of pig iron in the United States, by type of furnace

Type of furnace or equipment	1963		1964	
	Thousand short tons	Percent of total	Thousand short tons	Percent of total
Open hearth	57,291	78.8	65,206	75.5
Bessemer	1,603	2.2	949	1.1
Oxygen converter	7,082	9.8	12,446	14.4
Electric [1]	212	.3	325	.4
Cupola	3,597	4.9	3,704	4.3
Air	178	.2	170	.2
Direct castings	2,726	3.8	3,582	4.1
Total	72,689	100.0	86,382	100.0

[1] Includes a small quantity of pig iron consumed in crucible furnaces.

TABLE 10.—Consumption of pig iron in the United States, by districts and States

(Short tons)

District and State	1963	1964
New England:		
Connecticut	30,802	32,833
Maine and New Hampshire	1,741	1,999
Massachusetts	49,025	57,586
Rhode Island	42,660	42,408
Vermont	6,020	6,178
Total	130,248	141,004
Middle Atlantic:		
New Jersey	113,289	112,089
New York	3,837,813	4,606,010
Pennsylvania	17,460.390	21,373,302
Total	21,411,492	26,091,401
East North Central:		
Illinois	4,837,935	5,858,222
Indiana	9,863.042	11,367,746
Michigan	6,531,984	7.462,185
Ohio	12,556,922	15,092,990
Wisconsin	173,669	192,249
Total	33,963,552	39,973,392
West North Central:		
Iowa	74,685	88,128
Kansas and Nebraska	5,850	5,854
Minnesota	454,249	524,912
Missouri	33,490	39,687
Total	568,274	658,581
South Atlantic:		
Delaware and Maryland	4,844,795	5,691,698
Florida and Georgia	12,306	13,535
South Atlantic—Con.		
North Carolina	30,213	33,246
South Carolina	17,949	16,683
Virginia and West Virginia	2,229,954	2,375,911
Total	7,135,217	8,131,073
East South Central:		
Alabama	3,427,531	3,737,824
Kentucky, Mississippi, Tennessee	963,950	1,495,872
Total	4,391,481	5,233,696
West South Central:		
Arkansas, Louisiana, Oklahoma	7,990	12,144
Texas	942,427	1,332,816
Total	950,417	1,344,960
Rocky Mountain:		
Arizona and Nevada	92	-----------
Colorado, Idaho, Montana, Utah	2,230,501	2,510,068
Total	2,230,593	2,510,068
Pacific Coast:		
California and Hawaii	1,891,049	2,250,640
Oregon and Washington	16,417	46,884
Total	1,907,466	2,297,524
Grand total	72,688,740	86,381,699

PRICES

The average composite price of pig iron remained at $63.11 per long ton throughout 1964, and the average composite price for steel remained at 6.368 cents per pound throughout the year.[3]

TABLE 11.—Average value of pig iron at blast furnaces in the United States, by States

(Per short ton)

State	1955–59 (average)	1960	1961	1962	1963	1964
Alabama	$52.45	$56.52	$56.62	$57.46	$55.66	$53.83
California, Colorado, Utah	55.80	59.73	50.50	51.59	50.31	58.40
Illinois	56.57	60.30	60.42	59.10	57.52	57.74
Indiana	55.73	58.90	58.96	57.34	56.15	57.32
New York	58.37	62.54	60.05	59.13	67.40	62.45
Ohio	54.52	57.79	60.78	59.89	57.78	60.24
Pennsylvania	56.80	60.12	59.48	58.93	59.34	57.50
Other States [1]	56.82	58.06	57.44	57.66	60.26	57.99
Average	56.01	59.53	58.51	58.15	58.47	58.25

[1] Comprises Kentucky, Maryland, Michigan, Minnesota, Tennessee, Texas, West Virginia, Massachusetts, and Virginia.

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[3] Iron Age. V. 195, No. 1, Jan. 7, 1965, pp. 187–191.

TABLE 12.—Average prices of chief grades of pig iron

(Short tons)

Month	Foundry pig iron at Birmingham furnaces, 1964	Foundry pig iron at Cleveland furnaces, 1964	Bessemer pig iron at Valley furnaces, 1964	Basic pig iron at Valley furnaces, 1964
January-December	53.13	56.70	57.14	56.25

Source: Metal Statistics.

TABLE 13.—Free-on-board value of steel mill products in the United States, in 1963 [1]

(Cents per pound)

Product	Carbon	Alloy	Stainless	Average
Ingots	3.559	9.681	27.973	7.059
Semifinished shapes and forms	5.662	10.007	39.366	6.444
Plates	6.563	10.239	[2] 58.724	7.722
Sheets and strips	7.091	14.539	45.130	7.934
Tin mill products	9.183	----------	----------	9.183
Structural shapes and piling	6.366	9.181	----------	6.457
Bars	7.408	13.120	67.557	8.797
Rails and railway-track material	8.311	----------	----------	8.311
Pipes and tubes	10.275	16.988	144.230	11.462
Wire and wire products	12.604	36.491	83.310	13.697
Other rolled and drawn products	(3)	35.035	72.190	39.586
Average total steel	7.640	13.157	53.755	8.495

[1] This table represents the weighted average value based on the quantity of each type of steel shipped; therefore, it reflects shifts in the distribution of the 3 classes of steel.

[2] Includes unknown quantity of hot-rolled bars.

[3] Included with rails and railway-track material.

Source: Computed from figures supplied by the Bureau of the Census.

FOREIGN TRADE

The value of iron and steel mill products exported from the United States exceeded the value of imports by nearly 19 percent.

Imports in 1964 of iron and steel products were 6.6 million tons compared with imports of 5.6 million tons in 1963. The total quantity of iron and steel products exported was 4 million tons in 1964 and 2.7 million tons in 1963. The European Coal and Steel Community supplied 42 percent of the imports, Japan, 33 percent, and Canada, 15 percent.

TABLE 14.—U.S. imports for consumption of pig iron, by countries

(Short tons)

Country	1955-59 (average)	1960	1961	1962	1963	1964
North America: Canada	280,850	281,593	349,403	386,296	387,449	395,202
South America: Brazil	3,925	-----	-----	-----	-----	67,895
Eruope:						
Belgium-Luxembourg	-----	4,408	-----	-----	-----	-----
Finland	2,051	-----	-----	681	12,123	73,004
Germany:						
East	22	-----	-----	-----	-----	57,182
West	17,132	386	719	56,341	87,435	51,412
Netherlands	1,379	1,575	-----	-----	-----	-----
Norway	213	-----	-----	3,584	3,319	101
Portugal	879	-----	-----	-----	-----	1,051
Spain	17,873	21,551	19,113	42,416	45,161	11,683
Sweden	2,028	1,445	1,201	1,416	10,146	9,969
U.S.S.R.	310	1,298	396	-----	-----	-----
United Kingdom	10	-----	-----	94	8	-----
Total	41,897	30,663	21,429	104,532	158,192	204,402
Asia:						
India	2,322	6,742	-----	-----	-----	-----
Japan	2,135	-----	-----	-----	-----	-----
Total	4,457	6,742	-----	-----	-----	-----
Africa:						
Rhodesia and Malawi	1,021	392	-----	-----	-----	-----
South Africa, Republic of	14,414	7,543	4,096	5,030	76,696	68,620
Total	15,435	7,935	4,096	5,030	76,696	68,620
Oceania: Australia	2,432	3,914	2,252	4,216	22,997	352
Grand total: Short tons	348,996	330,847	377,180	500,074	645,334	736,471
Value	$18,690,611	$18,351,333	$20,511,391	$24,684,220	$28,936,920	$31,591,381

Source: Bureau of the Census.

TABLE 15.—U.S. imports for consumption of major iron and steel products

Products	1963		1964	
	Short tons	Value	Short tons	Value
Iron products:				
Bar iron, iron slabs, blooms, or other forms	265	$87,906	248	$71,221
Pipes and fittings:				
Cast-iron pipe and fittings	[r] 38,651	[r] 4,320,028	34,655	3,859,069
Malleable cast-iron pipe fittings	3,936	1,534,890	2,884	1,124,632
Castings and forgings	[r] 14,188	[r] 4,389,287	8,268	6,187,207
Total	[r] 57,040	[r] 10,332,111	46,055	11,242,129
Steel products:				
Steel bars:				
Concrete reinforcement bars	545,203	39,254,792	411,997	32,132,687
Solid and hollow, n.e.s	[r] 217,645	[r] 25,600,691	367,869	40,485,012
Hollow and hollow drill steel	[r] 3,078	[r] 1,319,541	4,757	1,988,406
Wire rods, nail rods, and flat rods up to 6 inches in width	[r] 801,353	[r] 76,986,562	952,767	88,455,563
Steel ingots, blooms, and slabs; billets, solid and hollow	260,355	24,831,885	344,760	36,526,720
Circular saw plates	[1] 146	70,639	(1)	819,951
Sheets and plates and steel, n.s.p.f	[r] 1,024,013	[r] 124,344,206	1,596,137	211,732,366
Tinplate, terneplate, and taggers' tin	82,941	14,197,413	80,693	13,754,201
Structural iron and steel	933,075	89,203,358	1,062,864	101,000,875
Rails for railways	[r] 10,123	636,452	10,843	1,044,333
Rail braces, bars, fishplates, or splice bars and tie plates	638	67,260	828	85,717
Steel pipes and tubes	[r] 743,515	[r] 106,333,167	787,111	114,464,632
Wire:				
Barbed	90,029	11,522,607	72,433	9,191,390
Round wire, n.e.s	[r] 285,780	[r] 50,517,341	377,979	65,529,795
Telegraph, telephone, etc., except copper, covered with cotton jute, etc	1,751	1,012,236	577	448,245
Flat wire and iron and steel strips	[r] 79,344	[r] 16,735,879	14,238	5,962,758
Rope and strand	[r] 47,641	[r] 13,688,654	52,129	15,319,067
Galvanized fencing wire and wire fencing	[r] 73,096	[r] 9,735,282	42,790	6,003,340
Iron and steel used in card clothing	(2)	[r] 372,362	(2)	160,559
Hoop and band iron and steel, for baling	27,707	3,701,291	30,479	4,019,129
Hoop, band and strips, or scroll iron or steel, n.s.p.f	[r] 27,664	[r] 8,173,376	44,119	16,257,407
Nails	[r] 308,867	[r] 41,678,183	310,437	44,643,750
Steel castings and forgings	[r] 16,483	[r] 5,042,574	16,038	4,075,042
Total	[r] 5,580,447	[r] 665,025,751	6,581,845	814,100,945
Advanced manufactures:				
Bolts, nuts, and rivets	[r] 68,551	[r] 19,650,311	74,624	22,744,338
Chains and parts	9,243	6,200,689	12,408	8,179,704
Hinges and hinge blanks	------------	2,014,423	------------	2,353,359
Screws (wholly or chiefly of iron or steel)	------------	[r] 3,853,173	------------	9,306,665
Tools	------------	[r] 13,216,052	------------	31,995.104
Other	------------	[r] 851,316	------------	1,139,019
Total	------------	45,785,964	------------	75,718,189
Grand Total	------------	721,143,826	------------	901,061,263

[r] Revised.

[1] Data are January–August; effective Sept. 1, 1963, saws were reported in number, September–December, 127,250 ($181,280), 1964, 190,840.

[2] Weight not recorded.

Source: Bureau of the Census.

TABLE 16.—U.S. exports of major iron and steel products

Products	1963		1964	
	Short tons	Value	Short tons	Value
Semimanufactures:				
Steel ingots, blooms, billets, slabs, and sheet bars	[r] 304,481	$24,665,086	856,445	$65,383,757
Iron and steel bars, and rods:				
Carbon-steel bars, hot-rolled, and iron bars	47,269	9,105,344	71,119	12,114,341
Concrete reinforcement bars	46,009	6,016,137	60,580	7,828,539
Other steel bars	24,901	12,352,386	42,831	17,221,341
Wire rods	24,033	4,145,703	33,939	5,717,371
Iron and steel plates, sheets, skelp, and strips:				
Plates, including boilerplate, not fabricated	139,483	26,389,591	176,613	35,199,150
Skelp iron and steel	2,482	234,626	29,574	3,283,888
Iron and steel sheets, galvanized	[r] 114,448	[r] 23,135,017	169,006	34,361,158
Steel sheets, black, ungalvanized	457,610	[r] 114,075,360	704,288	146,503,570
Strip, hoop, band, and scroll iron and steel:				
Cold-rolled	37,732	17,625,323	54,807	25,631,435
Hot-rolled	51,297	11,260,004	68,050	12,944,542
Tinplate and terneplate	342,363	51,059,805	351,642	52,709,046
Tinplate circles, cobbles, strip, and scroll shear butts	23,355	2,489,110	27,542	3,136,681
Total	[r] 1,615,463	[r] 302,553,492	2,646,436	422,034,819
Manufactures-steel mill products:				
Structural iron and steel:				
Water, gas, and other storage tanks (unlined), complete and knockdown material	21,031	9,759,863	15,023	7,527,697
Structural shapes:				
Not fabricated	[r] 153,143	[r] 22,548,595	236,115	36,840,374
Fabricated	[r] 170,836	[r] 37,479,578	89,914	32,551,537
Plates and sheets, fabricated, punched, or shaped	[r] 16,571	[r] 5,733,393	11,815	3,727,697
Metal lath	1,163	477,968	1,016	407,126
Frames, sashes, and sheet piling	8,235	1,953,252	14,387	2,730,908
Railway-track material:				
Rails for railways	44,045	5,970,153	45,536	5,859,758
Rail joints, splice bars, fishplates, and tieplates	45,323	9,183,035	10,079	2,639,019
Switches, frogs, and crossings	3,867	1,582,820	1,578	1,057,159
Railroad spikes	3,436	1,071,737	756	191,720
Railroad bolts, nuts, washers, and nut locks	6,023	1,429,887	727	401,671
Tubular products:				
Boiler tubes	11,840	8,066,150	13,865	8,792,275
Casing and line pipe	122,520	34,501,999	125,486	34,766,192
Seamless black and galvanized pipe and tubes, except casing, line and boiler, and other pipes and tubes	42,553	12,074,972	358,708	129,353,673
Welded black pipe	7,357	2,069,338	13,800	3,745,308
Welded galvanized pipe	12,017	2,610,468	15,029	3,450,149
Malleable-iron screwed pipe fittings	1,279	1,308,765	1,471	1,384,949
Cast-iron pressure pipe and fittings	119,397	15,450,543	32,153	5,764,250
Cast-iron soil pipe and fittings	7,246	1,803,201	6,623	1,607,468
Iron and steel pipe, fittings, and tubing, n.e.c	58,743	46,352,732	67,333	49,962,115
Wire and manufactures:				
Barbed wire	23,178	4,294,517	592	144,400
Galvanized wire	22,492	6,025,095	20,290	8,364,891
Iron and steel wire, uncoated	21,477	6,956,824	24,573	10,095,935
Spring wire	1,418	915,333	1,760	1,000,337
Wire rope and strand	9,227	5,042,761	10,549	6,306,286
Woven-wire screen cloth	1,540	[1] 2,138,642	1,701	[1] 2,629,550
All other	17,160	10,798,742	18,455	12,150,240
Nails and bolts, iron and steel, n.e.c.:				
Wire nails, staples, and spikes	4,348	3,587,563	4,482	4,518,324
Bolts, screws, nuts, rivets, and washers, n.e.c	19,580	22,465,248	21,636	26,589,950
Tacks	671	455,958	736	483,018
Castings and forgings: Iron and steel including car wheels, tires, and axles	76,766	25,533,033	98,239	35,504,895
Total	[r] 1,054,482	[r] 309,642,165	1,264,427	440,548,878

See footnotes at end of table.

TABLE 16.—U.S. exports of major iron and steel products—Continued

Products	1963		1964	
	Short tons	Value	Short tons	Value
Advanced manufactures:				
Building (prefabricated and knockdown)		[r] $6,608,289		$7,668,546
Chains and parts	8,189	11,201,215	13,732	13,454,945
Construction material	8,099	5,888,865	12,461	7,288,026
Hardware and parts		24,422,387		27,354,061
House-heating boilers, and radiators		6,197,711		7,259,766
Oil burners and parts		9,712,142		10,296,030
Plumbing fixtures and fittings		4,987,304		6,076,797
Tools		39,725,808		66,788,075
Utensils and parts (cooking, kitchen, and hospital)		3,298,068		2,989,943
Other		53,391,629		57,202,018
Total		[r] 165,433,418		206,378,207
Grand total		[r] 777,629,075		1,068,961,904

[r] Revised.

[1] Includes wire cloth as follows 1963, $1,638,819 (3,404,155 square feet); 1964, $2,035,676 (3,707,046 square feet).

Source: Bureau of the Census.

WORLD REVIEW

The United States led world production of pig iron (including ferroalloys) to a new high with an increase of 14 million tons. The increase in world steel production was led by the United States, which had an increase of nearly 18 million ingot tons. Japan again had the largest percentage increase in production with 29 percent more ingot steel produced in 1964.

TABLE 17.—World production of pig iron (including ferroalloys) by countries[1] [2]

(Thousand short tons)

Country[1]	1955–59 (average)	1960	1961	1962	1963	1964[p]
North America:						
Canada	3,725	4,436	5,064	5,427	6,059	6,707
Mexico	493	756	864	912	947	1,068
United States	71,771	68,620	66,717	67,636	73,853	87,922
Total	75,989	73,812	72,645	73,975	80,859	95,697
South America:						
Argentina	35	198	437	438	467	649
Brazil	1,439	1,965	2,050	2,337	2,778	2,484
Chile	353	293	314	440	480	482
Colombia	147	204	208	164	224	243
Venezuela	----------	----------	6	136	333	357
Total	1,974	2,660	3,015	3,515	4,282	4,215
Europe:						
Austria	1,954	2,467	2,500	2,339	2,326	2,434
Belgium	6,223	7,223	7,104	7,439	7,622	9,327
Bulgaria	75	212	227	246	292	1,026
Czechoslovakia	3,934	5,225	5,529	5,767	5,847	6,361
Denmark	60	80	73	76	76	77
Finland	122	151	168	377	413	653
France	13,129	15,921	16,372	15,716	16,010	17,728
Germany:						
East	1,857	2,199	2,239	2,287	2,370	2,491
West	22,677	28,372	28,033	26,732	25,253	29,963
Hungary	1,034	1,390	1,455	1,543	1,544	1,647
Italy	2,269	3,113	3,528	4,054	4,264	3,996
Luxembourg	3,637	4,173	4,226	3,965	3,954	4,620
Netherlands	902	1,485	1,606	1,732	1,884	2,147
Norway	556	794	834	798	821	976
Poland	4,087	5,030	5,258	5,854	5,947	6,220
Portugal	[3] 30	45	134	248	265	297
Rumania	754	1,118	1,211	1,666	1,881	2,121
Spain	1,321	2,124	2,340	2,374	2,187	2,045
Sweden	1,570	1,799	2,094	2,164	2,220	2,434
Switzerland	49	[e] 60	[e] 60	[e] 60	49	35
U.S.S.R.[4]	41,596	51,541	56,100	60,919	64,697	68,784
United Kingdom	14,667	17,655	16,517	15,335	16,342	19,347
Yugoslavia	794	1,123	1,161	1,216	1,168	1,186
Total[4]	123,297	153,300	158,769	162,907	167,432	185,915
Asia:						
China	[5] 9,679	30,300	[e] 16,500	[e] 16,500	[e] 18,700	[e] 19,800
India	2,466	4,705	5,621	6,522	7,431	7,432
Japan	8,034	13,604	18,059	20,325	22,525	27,017
Korea:						
North	354	959	1,047	1,365	1,305	[e] 1,510
South	6	15	10	2	6	1
Taiwan	23	26	58	69	60	68
Thailand	4	7	6	6	7	6
Turkey[6]	244	272	260	323	434	[e] 440
Total[4]	20,810	49,888	41,561	45,112	50,468	56,274
Africa:						
Rhodesia (formerly Southern)	78	95	243	266	276	287
South Africa, Republic of	1,648	2,197	2,566	2,663	2,691	3,181
United Arab Republic (Egypt)	39	163	192	225	----------	----------
Total	1,765	2,455	3,001	3,154	2,967	3,468
Oceania: Australia[7]	2,448	3,240	3,549	3,879	4,113	4,523
World total[e]	226,283	285,355	282,540	292,542	310,121	350,092

[e] Estimate.

[p] Preliminary.

[1] Pig iron is also produced in Republic of the Congo, but quantity produced is believed insufficient to affect estimate of world total.

[2] This table incorporates some revisions. Data do not add to totals shown due to rounding where estimated figures are included in the detail.

[3] Average annual production 1958–59.

[4] U.S.S.R. in Asia included with U.S.S.R. in Europe.

[5] Based on figures from Chinese sources. 1958 does not include approximately 4,000,000 tons of substandard grade iron produced at small plants. 1959 production probably includes pig iron obtained from reworking the low-grade product of 1958 and an unreported quantity (probably relatively small) of substandard iron from small plants most of which were shut down early in the year.

[6] Includes foundry iron.

[7] Includes scrap.

TABLE 18.—World production of steel ingots and castings by countries [1]

(Thousand short tons)

Country	1955–59 (average)	1960	1961	1962	1963	1964 [p]
North America:						
Canada	5,033	5,809	6,488	7,173	8,190	9,131
Mexico	1,117	1,657	1,882	1,896	2,237	2,564
United States [2]	104,734	99,282	98,014	98,328	109,261	127,076
Total	110,884	106,748	106,384	107,397	119,688	138,771
South America:						
Argentina	297	305	486	725	1,006	1,394
Brazil	1,644	2,531	2,756	[e] 2,870	3,123	3,340
Chile	401	465	400	546	539	600
Colombia [3]	112	190	212	173	245	[e] 240
Peru	[4] 40	66	83	79	80	83
Venezuela	[e] [4] 55	52	83	248	401	485
Total	2,549	3,609	4,020	4,641	5,394	6,142
Europe:						
Austria	2,495	3,487	3,418	3,274	3,249	3,521
Belgium	6,835	7,923	7,728	8,115	8,298	9,624
Bulgaria	177	279	375	466	508	522
Czechoslovakia	5,769	7,460	7,764	8,421	8,375	9,234
Denmark	283	349	356	405	396	445
Finland	220	280	305	336	346	391
France	15,304	18,907	19,211	18,857	19,214	21,804
Germany:						
East	3,174	3,678	3,796	3,993	3,997	4,246
West	29,701	37,589	36,881	35,895	34,830	41,159
Greece	93	[e] 140	[e] 150	[e] 170	230	[e] 240
Hungary	1,721	2,078	2,263	2,572	2,617	2,606
Ireland	33	44	31	21	22	22
Italy	6,862	9,071	10,283	10,755	11,196	10,795
Luxembourg	3,795	4,502	4,534	4,420	4,445	5,025
Netherlands	1,394	2,141	2,173	2,301	2,582	2,924
Norway	355	540	550	538	599	678
Poland	5,857	7,585	7,974	8,470	8,823	9,449
Rumania	1,051	1,991	2,344	2,702	2,981	3,350
Spain	1,609	2,115	2,579	2,547	2,747	3,017
Sweden	2,706	3,547	3,926	3,982	4,299	4,894
Switzerland [3]	235	303	327	351	342	380
U.S.S.R. [5]	57,328	71,973	77,994	84,113	88,403	93,691
United Kingdom	22,826	27,222	24,737	22,950	25,222	28,918
Yugoslavia	1,138	1,590	1,689	1,758	1,750	1,849
Total [5]	170,961	214,794	221,388	227,412	235,471	258,784
Asia:						
China	[6] 7,500	[6] 20,340	10,500	11,000	13,000	[e] 15,000
India	2,107	3,622	4,502	5,676	6,582	6,649
Israel	[e] [7] 20	45	68	88	74	[e] 74
Japan	13,631	24,403	31,160	30,364	34,724	43,871
Korea:						
North	313	707	855	1,157	1,127	1,157
South	22	55	73	163	176	154
Taiwan	109	220	218	201	303	331
Thailand	6	8	9	8	[e] 8	[e] 8
Turkey	205	330	356	323	400	492
Total [5]	23,913	49,730	47,741	48,980	56,394	67,736
Africa:						
Rhodesia (formerly Southern)	65	95	101	88	55	[e] 55
South Africa, Republic of	1,907	2,328	2,738	2,903	3,124	3,414
United Arab Republic (Egypt)	108	152	174	209	217	[e] 275
Total	2,080	2,575	3,013	3,200	3,396	3,744
Oceania: Australia	3,200	4,137	4,351	4,667	5,126	5,603
World total [e]	313,590	381,590	386,900	396,300	425,470	480,780

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[e] Estimate.

[p] Preliminary.

[1] This table incorporates some revisions. Data do not add exactly to totals shown because of rounding where estimated figures are included in the detail.

[2] Data from American Iron and Steel Institute. Excludes production of castings by companies that do not produce steel ingots.

[3] Including secondary.

[4] Average annual production 1958–59.

[5] U.S.S.R. in Asia included with U.S.S.R. in Europe.

[6] Claimed figures for 1959 and 1960 appear to be exaggerated by a fifth or more.

[7] Average annual production 1957–59.

NORTH AMERICA

Canada.—The Steel Co. of Canada, Ltd. (Stelco), ordered a six-strand curved mold continuous casting machine capable of casting 350,000 tons per year. Stelco's first continuous casting unit was a vertical machine. Stelco was to build the first hydrochloric acid pickle line in Canada at its Hilton works. The new line will be able to pickle steel 74 inches wide, with maximum speed of 800 feet per minute.

The four largest Canadian producers of basic steel, Algoma Steel Corp., Ltd., Dominion Foundries & Steel, Ltd., Dominion Steel & Coal Corp., Ltd., and Stelco were all increasing the pattern of vertical integration from iron ore to finished product.

Imperial Oil, Ltd., planned to spend about $7 million in construction of an experimental research plant to develop a process to reduce iron ore by using petroleum products. The research plant will be at the company refinery site at Dartmouth, Nova Scotia.

Dominion Bridge Co., Ltd., planned a new electric melting shop and continuous casting machine in a major modernization of its facilities in Selkirk, Manitoba.

An integrated steel mill estimated to cost $225 million was planned to be built either at Becancour, about halfway between Montreal and Quebec, or at Contrecoeur, about 30 miles east of Montreal. Either site will have the advantage of being a seaport on the St. Lawrence River. New Brunswick announced plans for a $64 million steel mill in the northeastern part of that province.

A new integrated steel producer will be the first in Western Canada, when Consolidated Mining & Smelting Co. of Canada, Ltd. (Cominco), starts to make steel using pig iron that it produces at Kimberley, British Columbia.

SOUTH AMERICA

Argentina.—A new integrated steel plant, Altos Hornos Zapla, planned and built by DEMAG A.G. of West Germany, was commissioned in October. The plant is at Palpalá in the vicinity of an iron ore deposit in the Sierra de Zapla and will use local charcoal in the blast furnace. Production capacity was 131,000 tons of ingot steel annually.

A fully automatic rolling mill with an annual production capacity of 240,000 tons was opened at Avellaneda, near Buenos Aires.

Brazil.—Brazilian and Mexican interests were cooperating in the erection of a plant projected by Usina Siderurgia da Bahia S.A. (USIBA). The Governor of Bahia announced that the plant will employ the reduction process developed by Hojalata y Lámina S.A. of Mexico, which produces sponge iron.[4]

Chile.—Compañia de Acero del Pacifico S.A. (CAP) completed financing for its second blast furnace at Concepcion. The furnace will have a 20-foot, 9-inch hearth diameter, and will be equipped for supplemental oil injection through the tuyères. Secondary development will provide for oxygen enrichment of the hot blast and high top-pressure. CAP also uses oxygen injection through lances in the open-hearth roof.[5]

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[4] Blast Furnace & Steel Plant. V. 52, No. 5, May 1964, pp. 438–439.

EUROPE

Austria.—Vereinigte Österreichische Eisen U. Stahlwerke, (VOEST) has developed a converter vessel transfer car for Linz Donawitz (LD) oxygen steelmaking plants. This car enables the practically continuous operation of a one-furnace LD converter plant by the use of two interchangeable furnace shells, since workers can be relining one vessel while the other is in operation.

Czechoslovakia.—A new system of central control, the first of its kind in Czechoslovakia, enables the dispatcher to follow and control, on three panels, the operation of all the casting cranes in the preparation and transfer of the casting equipment. The system is equipped with automatic temperature recorders, two-way radio, and telecommunications equipment.

VOEST announced the signing of a contract for three oxygen process (LD) steel converters for installation in a new steel complex at Kosice, Czechoslovakia. Each LD unit is to be 120 tons rated capacity.

European Coal and Steel Community (ECSC).—Steel ingot production of 91 million short tons was 13 percent greater in 1964 than in 1963 for ECSC. All Community countries except Italy showed gains.

ECSC exports to Great Britain were expected to drop about 75 percent because of the British Labor Government's import duty surcharge of 28 percent.

A unique feature of the new Chertal works of the S.A. Métallurgique d'Espérance-Longdoz (Longdoz) was the transportation of hot metal 14 miles from the Seraing plant by torpedo-type ladle cars on the Belgium National Railway. A total car weight of 330 tons is necessary to carry 165 tons of hot metal at 1,300° C with a loss in hot metal temperature of only about 5° per hour. The Chertal works utilized two symmetrical oxygen converters of 150-ton capacity, capable of producing steel either by LD or LDAC techniques. The high phosphorus hot metal received required the furnaces to be used as LDAC powdered lime units.[6]

The LDAC oxygen steelmaking process introduced into Belgium in 1963 was expected to account for about 36 percent of the country's steelmaking capacity by 1967. The powdered lime in the LDAC process enabled users to refine the high phosphorus hot metal which comes from European ores.

Syndicat Siderurgique Maritime S.A. (SIDEMAR) started erection of a large steel mill complex at Zelzate on the Ghent-Terneuzen canal. The first plant to be erected was a cold rolling mill, later units will include two blast furnaces each with a productive capacity of 3,000 tons of pig iron per day, and two LD-Arbed converters of 200 metric tons each.

Steel ingot production in France set a record during 1964. Total production was up nearly 13 percent, but production by the oxygen processes increased by over 65 percent, representing 11 percent of total production.

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[5] Iron and Steel Engineer. V. 42, No. 1, January 1965, pp. 144, 147.

[6] Journal of Metals. Belgium and Its New Steelmaking Facilities. V. 16, No. 1, January 1964, pp. 37–41.

The Research Institute of the French Steel Industry (IRSID) has systematically studied the application of its powder-blowing technique to steelmaking for the last 10 years. The study of its application to electric furnace steelmaking has led to the development of precise and rapid methods of dephosphorization, desulfurization, and a recarburization and dissolution of steelmaking additives. These methods have now been introduced to about 15 electric-furnace steel works in France and other European countries, where they are applied mainly for recarburization or dephosphorization.[7]

The shift to oxygen steelmaking has been reflected in West Germany for August Thyssen-Hütte A.G. has announced the installation of two 180-ton capacity basic oxygen steelmaking furnaces.

The merger of August Thyssen-Hütte A.G. with Phoenix-Rheinrohr A.G. will form the largest steel combine in Europe with a combined capacity of over 8 million tons.

Mannesmann A.G. of Dusseldorf acquired an interest in Concast, Inc., of New York. Mannesmann A.G. installed a new rolling mill for heavy plate of 300,000 tons capacity, to replace three old mills with a joint annual capacity of 200,000 tons. The new mill requires 443 men for operation as compared with 684 men for the 3 old mills.

Italsider was completing a new integrated steelworks at the port of Taranto in southern Italy. Major steelmaking units for this plant are two 330-ton LD basic oxygen converters to be controlled by a CAE–510 digital computer of French manufacture. In the opposite end of the country, Italsider has been rebuilding its plant at Trieste. The old port of Servola has been completely replaced, and modern ore handling equipment installed at the new location. After the new blast furnace is fired and the current furnace modernized, output of pig iron will be about 176,000 net tons annually.

Italy has been importing plate and hot coils from Czechoslovakia and the U.S.S.R.

The Netherlands was also planning to increase steel production capacity. The Koninklijke Nederlandsche Hoogovens en Staalfabrieken N.V. (Hoogovens), the only fully integrated Netherlands concern for producing steel, was rapidly expanding its oxygen steelmaking, with three 100-ton LD converters replacing two 60-ton converters installed in 1958. The LD steelmaking is controlled with an analog computer. The other two steel producing concerns in the Netherlands, Koninklijke Demka Staalfabrieken, N.V., and the N.V. Nederlandsche Kabelfabrieken were not fully integrated and are principally concerned with expanding and modernizing their mill capacities.

Hungary.—A new organization to coordinate steel production for Hungary, Czechoslovakia, and Poland was established with headquarters in Budapest. The organization—Intermetall—will be the first Council for Mutual Economic Aid (COMECON) body with power to put its resolutions into effect, without endorsement by superior authorities in the member country concerned. Bulgaria and East Germany have already shown some interest in joining.

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[7] Journal of Metals. Powder Blowing Techniques for Electric Steelmaking. V. 16, No. 11, November 1964, pp. 885–890.

Hungarian researchers investigating the cause of brittleness in titanium-bearing steel apparently have confirmed the fact that nitrogen tied up by the titanium causes the brittleness.

Poland.—The first steel from a new open-hearth furnace was reported in July at the Zawiercie Steel Works. Construction of this furnace represented the first step in the rebuilding of the 90-year-old Zawiercie foundry, whose eventual output will be 800,000 tons of steel.

It was also planned to construct six more large foundries, each of which will be in a particular metalworking area. COMECON plans to increase Polish and Czech steelmaking capacity by 10 percent per year for the next 5 years.

Poland exported more than 900,000 tons of steel in 1964, securing orders for high-grade steel products from India, West Germany, and Switzerland, among others. Use of a computer to direct rolling mill operations at the Babedy Steelworks is reported to have reduced scrap by almost half.

The amount of research conducted in the COMECON countries to reduce the use of nickel and molybdenum indicates shortages of these metals.

Spain.—In common with steel producers all over the world, the steelmaking companies in Spain were expanding, modernizing, and merging. Altos Hornos de Vizcaya S.A. (AHV) has tendered 25 percent of its capital stock to United States Steel Corp. in exchange for technical and economic assistance. United States Steel will also give technical and vocational training for a period of 10 years. AHV put two LD basic oxygen converters into operation.

The Sociedad Union de Siderurgicas Asturianas (UNINSA) contracted with Kaiser Engineers for a two-phase study. The first phase will be to assess present facilities of the UNINSA group, the second phase to plan an entirely new integrated steel complex on the Asturian coast in the north. Armco Steel has a technical assistance and vocational program in cooperation with Empresa Nacional Siderurgica Española S.A. (ENSIDESA) at Aviles, on the Bay of Biscay. Koppers Co. built the second blast furnace for ENSIDESA at Aviles and was building a third.

Insufficient domestic production caused Spain to suspend import duties on bars, ingots, blocks, blooms, and slabs. Suspension was to remain in effect until December 2, 1964.

Sweden.—A rotating furnace for producing pig iron directly from iron ore has been developed by Stora Kopparbergs Bergslag a.-b. of Sweden. The new process permits a high degree of silicon and phosphorus refinement, the use of pulverized ore without sintering or pelletizing, cheaper fuels, and cheaper coke. Since the rotating cylindrical furnace used is very similar to that used in the Kaldo steelmaking process this may lead to a more successful direct reduction process for making steel.[8]

Sandvik Steelworks Co., Ltd., furnished up to 80 percent of the steel for Swiss watchmakers. A recent innovation was the use of stainless steel for the watch spring, which is said to last up to 10 times as long as the older type of carbon steel spring. The Motala Works claims a world record for producing a 1,200-meter-long continuous steel casting in 4 hours. The casting unit was constructed by E. A. Olsson, of Zurich, Switzerland.

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[8] Mining Magazine (London). V. 110, No. 7, July 1964, pp. 51, 53.

Switzerland.—E. A. Olsson, the Swiss firm that holds the patent on a continuous casting machine such as that installed at Motala, has filed a patent for a technique that protects the surface of continuously cast steel from decarburization. The Olsson patent recommends that powders be suspended in the cooling water. As these powders come into contact with the hot metal surface, they sinter and form a protective coating.[9]

U.S.S.R.—Oxygen steelmaking was not increasing as rapidly in the Soviet Union as in other countries. Open-hearth steelmaking amounted to about 84.3 percent in 1964. Trouble was reported in the Soviet Union with badly sorted scrap metal contaminated with nonferrous metals and alloy waste, combined with low-quality pig iron with up to 40 percent having a sulfur content in excess of the maximum. If the planned rate of 20 million short tons of oxygen steel per year by the end of 1965 is realized, it will mean doubling the output of oxygen converter steel in 1965. The changeover to oxygen converters undoubtedly has been slowed because the actual cost of making steel in the open hearth is about 8 percent less than that for oxygen converter steel. This is due in large measure to the fact that a ton of hot metal costs from 1.7 to 2 times more than a ton of steel scrap.

Although oxygen steelmaking was not increasing rapidly, continuous casting was beginning to be used. There were 14 continuous casting installations in 10 different steel plants in U.S.S.R. Soviet steelmakers are using continuous casting for nearly all grades of carbon steel and many types of alloy steel. Billets run from 5 to 12 inches square, and slabs as large as 8 by 55 inches. The Soviet researchers are working to produce stainless steel with low nickel content by which they hope to save the country 1,000 tons per year of nickel at present rates of production.

Soviet planners expect the Yenisei River Basin to become the industrial heart of the Soviet Union in the next 20 years.

United Kingdom.—Six separate functions of a hot strip mill at the Spencer works of Richard Thomas and Baldwins, Ltd., are controlled by means of an online computer. The digital computer controls slab tracking, mill facing, mill setup and width control, temperature control, and production and engineering logging. Use of this computer allows the final product to be dimensionally accurate to plus or minus 0.002 inch.

A vacuum-degassing plant coupled with induction stirring can treat 110 tons of steel at a time at the Samuel Fox & Co. Ltd., Stocksbridge works, near Sheffield. Carbon-chromium bearing steels are being handled in this unit. The unit reaches a vacuum level of less than 100 microns in 10 minutes and holds this level for a further 10 minutes to complete the degassing with a temperature loss of 35° to 40° C. only. The induction stirring action speeds up the process by constantly renewing the surface.

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[9] Journal of Metals. V. 16, No. 8, August 1964, pp. 617, 618.

Three out of the four oxygen steelmaking processes were operating in the Scunthorpe region of England. Appleby-Frodingham Steel Co. used the Ajax process, Richard Thomas and Baldwins' Redburn works used the Rotor process, and Lysaght's Scunthorpe Works recently commissioned two LDAC units with the result that oxygen steel capacity at Scunthorpe was about 2.5 million tons per year.

The use of oxygen in the steelmaking revolution is represented in the United Kingdom by the fact that there was 96 cubic feet of oxygen used per ingot ton produced in 1958, while the corresponding figure for 1963 was 620 cubic feet.

Two companies have gone onstream with the Kaldo process of basic oxygen steelmaking. The Park Gate Iron & Steel Co., Ltd., installed the Kaldo furnaces as part of the company's $90 million development.

Shelton Iron & Steel, Ltd., combined two 55-ton Kaldo furnaces with its continuous casting facilities. The continuous casting machines consist of three three-strand units and one large two-strand unit which casts blooms up to 24 by 17 inches. Charges in the Kaldo unit consist of about 35 percent scrap.

Steel, Peech & Tozer have opened up new research laboratories costing about $3 million devoted to quality control and process development.[10]

Richard Thomas & Baldwins has patented an infrared analytical apparatus which gives a detailed analysis of the carbon content of steel in about 3 minutes. A water treatment plant that reduces the suspended solids in the mill effluent from approximately 300 parts per million to not more than 3 parts per million without the addition of chemicals has been installed at Appleby-Frodingham Steel works at Scunthorpe.

The British Iron & Steel Research Association (BISRA) completed the second set of facilities at the association's Battersea laboratories. The new addition provides space for a heavy plant laboratory, drawing office, and other facilities. Decision to construct an entirely new ironmaking research and pilot-plant laboratory on the northeast coast near Middlesborough was announced. This facility, expected to be completed early in 1966, will make it possible to concentrate, in one place, all research on ironmaking and materials handling.

A complete computer system to direct all operations of the mill from the reheat furnace to the downcoiler has been ordered by the Steel Co. of Wales, Ltd. (Stelco), for its Abbey Works in Port Talbot, Wales. The 80-inch hot strip mill at the Abbey Works, the widest in Europe, has a 3 million-ingot-ton annual capacity. It consists of five reheat furnaces; a five-stand horizontal roughing mill; three edging stands; a six-stand continuous finishing mill, and three downcoilers.

A relatively low-cost mechanical/magnetic system of automatic gage control for a wide hot-strip mill has been developed at the Ebbw Vale works of Richard Thomas & Baldwins. Signals from an X-ray gage at the exit end of the mill are used to control the screw-down settings on the mill stands. The equipment gives more uniform gage than is possible without automatic control. Variations rarely exceed 0.002 inches even in silicon steels.

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[10] Metallurgia (Manchester, England). New Research Laboratories at Steel, Peech & Tozer. V. 69, No. 416, June 1964, pp. 296–300.

Investigations at the British Iron & Steel Research Association (BISRA) have developed a mechanism that gives accurate quick acting automatic position control of the press tool in forging operations. Work on integrating the manipulator with the press tool inspired the Parks forge unit, which allows basic forging operations to be carried out automatically.

The strike against Stelco which lasted 6 weeks ended in February.

A stainless steel is to be used, because of its nonmagnetic properties, for concrete reinforcement in the construction of a new physical laboratory for investigation of electromagnetic phenomena.

ASIA

India.—The Rourkela steelworks of Hindustan Steel, Ltd., was being increased from 1 million tons to 1.8 million tons of annual capacity by new mill equipment ordered from DEMAG A.G. of West Germany.

Blast furnace No. 4 was being built at the Durgapur, West Bengal, steelworks to complete second stage construction. Great Britain and Japan have offered India financial assistance to start work on the third stage, which would double the annual productive capacity to 3 million ingot tons. Agreement to build an additional blast furnace at Bhilai Steel plant has been reached by the U.S.S.R. and the Government of India. The new furnace, with annual productive capacity of about 700,000 tons of pig iron, will be in addition to the three blast furnaces currently operating at Bhilai.

VOEST of Austria was to supply three LD furnaces to Rourkela with an annual capacity of 750,000 tons. Fried. Krupp Industriebau was to install two 60-ton open hearth vessels for the total capacity of 250,000 tons.

A new Indian company, established to manufacture alloy steels, has negotiated a loan of over $3 million from the International Finance Corp. The company Mahindra Ugine Steel Co., Ltd., was a partnership of Société d'Électro-Chimie, d'Électro-Métallurgie, et des Aciéries Electriques d'Ugine (Ugine) and of Mahindra, Ltd., of Bombay. The new plant, about 65 miles from Bombay, at Khopoli, will have the capacity of 18,000 tons of finished alloy steel products and cost about $14 million. The Government of India announced that the U.S.S.R. had agreed to finance construction of the first section of the Bokaro steel plant which will have a 1.5-million ton annual capacity. The Government has allowed two private sector steel companies, Tata Iron & Steel Co., Ltd., and Indian Iron & Steel Co., Ltd., to expand existing capacity from 2 million and 1 million tons per year to 3 million and 2 million tons per year, respectively, during the Fourth Plan.

Japan.—Total Japanese steel production was up about 20 percent over that of 1963, but its oxygen converter production was up 29 percent over that of 1963.

Japan produced more basic oxygen steel than any country and was the only country in which the converter steel production was higher than open-hearth production. Of the 80 LD plants in operation at the end of 1964, 19 were in Japan. The Hikari works of Yawata Iron & Steel Co., Ltd., have been continuously casting wide slabs since 1960. The works have continuously cast slabs as wide as 49 inches by 4 inches thick.

Japan, the leader in oxygen steel, started to expand its continuous casting. Japanese steelmakers have concast systems at the Sumitomo Metal Industries, Ltd., Osaka Special Steel Works, and Yawata's Hikari Stainless Steel Works. There is a Mannesmann unit at the Nippon Koshuha Steel Co., Ltd., Hachinoe Works, and one Hitachi unit operating along experimental lines. Many smaller companies have announced plans for continuous casting, most of them preferring the new compact Swiss concast system, which is only about 30 percent as high as the vertical systems.

Twin 70-ton Kaldo converters formed the basis for a steel works ordered by Sanyo Special Steel Co., Ltd., to be built by Krupp of West Germany. Annual capacity was estimated at 300,000 tons of high-quality steel. Nippon Kokan K.K. started construction of a new integrated steel-works which would include six blast furnaces and three converter shops, with an annual capacity of 6 million tons. A new blooming and rolling mill capable of handling steel up to 170 inches in width was ordered for the Wakayama Works of Sumitomo Metal Industries, Ltd., of Tokyo, for approximately $3 billion.

Tokai Iron & Steel Co., Ltd., became an integrated producer during 1964, blowing in a blast furnace with a capacity of 3,850 tons per day as well as two 135-ton oxygen converters. Iron from the new blast furnace which is not used directly as hot metal will be granulated instead of pigged. The plant is on 1,600 acres of reclaimed land.

AFRICA

Ghana.—Ghana had a new steelworks with an annual capacity of 30,000 tons of finished products. Construction at a cost of over $5 million was handled by a British manufacturer.

South Africa, Republic of.—Stainless steel production by direct smelting of Transvaal ores was announced by Rand Mines, Ltd. Stainless steel ingots will be shipped to Eastern Stainless Steel Corp. of the United States, where they will be rolled. Finished products will then be returned to South Africa.

OCEANIA

Australia.—As construction for the $90 million steelmaking works at Whyalla on the Spencer Gulf of South Australia was being completed, Broken Hill Pty. Co., Ltd. (BHP), announced a program expansion in Western Australia at Kwinana to cost nearly $90 million. Steel at Whyalla will be made in 100-ton basic oxygen converters.

A new process to provide a galvanized matt finish to sheet steel should more than double the life of a motor-car body. This new corrosion resistant steel was produced by John Lysaght (Australia), Ltd.

BHP has had to recruit steel workers in Great Britain.

TECHNOLOGY

Approximately $1,500 million was spent in 1964 by iron and steel companies for capital improvements. This brings the cumulative totals since World War II to over $18,000 million. Need for this investment results from the advances in steelmaking technology, and most of this expenditure is to improve range and quality of products and efficiency of operations rather than to expand capacity.

Continuous casting, starting from its first commercial production early in 1963, was in operation or in the plans of 15 different steelworks. A double-strand unit, which will cast slabs from 8 to 25½ inches to 5⅛ by 50½ inches, is being installed in the Midland Works of Crucible Steel Co., Pittsburgh, Pa. The Wisconsin Steel Works of International Harvester Co., south Chicago, Ill., will have a 120-ton-per-hour vertical continuous casting machine that will produce eight strands of 5- and 6-inch square billets. National Steel Corp. has ordered a four-strand continuous casting machine for its Weirton, W. Va., works. This machine will manufacture over 1 million tons of heavy slabs per year, ranging from 7 to 9 inches in thickness, and from 30 to 40 inches in width. A two-strand continuous casting machine, producing slabs up to 12 inches thick by 80 inches wide, has been ordered in a modernization program for the Phoenix Steel Corp. Operations at the Dunkirk, N.Y., continuous casting plant of the Roblin Steel Co. started on January 29. Production should be about 120,000 tons per year. Soule Steel Co. of California installed a continuous casting machine having two-strands producing 5-inch-square billets. This machine is of the curved-mold type.

United States Steel has reported that it will construct a large-scale continuous casting unit at its Gary Steel works.

A new low-head continuous casting unit producing 6-strand 4-inch-square billets is to be installed in Stelco's Hilton Works at Hamilton, Ontario. The unit will be in Stelco's No. 2 open-hearth shop and will produce 350,000 tons of billets annually.

Western Gear Corp. has signed a long-term agreement with the Swiss firm of E. A. Olsson, A.G., to manufacture and sell continuous casting machinery in the United States, Mexico, and Canada.

The molten metal level in the mold of a continuous casting machine generally is controlled by varying the rate of withdrawal of the cast billet from the mold. However, a more uniform billet results from uniform withdrawal speeds. Also, varying the rate of withdrawal necessitates varying the amount of cooling water applied. As these problems are compounded by multiple strand units, it becomes evident that systems are going to have to be devised to control the level in the mold and perhaps in the tundish by other means.[11]

Tensile and fatigue tests, both longitudinal and transverse, together with tests of inclusion occurrence, show that continuously cast steel is equivalent to ingot cast steel. Center shrinkage cavities are closed completely by hot reductions of 4 to 1 or greater.[12]

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[11] Iron Age. Continuous Casting Takes Cues From "Strategic" Controls. V. 194, No. 6, Aug. 6, 1964, pp. 62–63.
Iron and Steel Engineer. Metal Level Is Controlled Automatically in Continuous Casting Machine. V. 41, No. 10, October 1964, p. 168.
Steel. Controls Metal Level in Continuous Casting. V. 155, No. 8, Aug. 24, 1964, pp. 87–88.

A single-strand machine designed to cast a slab 9.8 inches thick by 63 inches wide is in production at the Dillinger Hüttenwerke, in West Germany.[13]

BISRA has announced that it has cast in a continuous casting machine short lengths of dog-bone shaped blanks which have been successfully rolled to wide-flange beams by Algoma Steel Corp., Ltd.

Controlled pressure pouring by forcing molten metal with compressed air up through a refractory tube into a graphite mold cavity filled with an inert gas is a technique that is growing more slowly than oxygen steelmaking or continuous casting. However, pressure poured slabs of both carbon and stainless steel composition are being evaluated by several companies.[14]

Vacuum Degassing.—Lukens Steel Co. has installed a 150-ton Dortmund-Hörder (D-H) vacuum degassing unit. It is to be operated in conjunction with the company's two existing 100-ton electric furnaces and will take care of a third new 145-ton furnace scheduled for start up in 1965.

Bethlehem Steel Corp. announced the installation of a 300-ton vacuum degassing unit at its Lackawanna plant.

Republic Steel Corp. announced installation of a vacuum degassing unit capable of handling 150-ton ladles of steel in its South Chicago plant. The degassing installation of Jones & Laughlin Steel Corp. is built so that it works on a ladle placed on a transfer car. Also alloying elements can be added under vacuum to the ladle during the degassing treatment cycle.

The three main techniques of degassing are—stream, ladle, and incremental degassing. In stream degassing the ladle is positioned over an evacuated chamber containing another ladle or ingot mold. When the nozzle is opened steel sprays into the evacuated chamber and gases are given off by the steel as it falls. In ladle degassing, as the name implies, the ladle is placed in the evacuated chamber and usually given extra stirring to be sure of complete degassing, which occurs only at the surface. What is spoken of an incremental degassing is exemplified by the D-H and R-H processes. In the D-H process either the chamber or the ladle moves up and down and small quantities of steel are degassed each time, which then fall back into the ladle. In the R-H process some steel moves up into the evacuated chamber through one leg and then out through a different leg as more untreated steel moves up, giving a continuous flow.[15] In one method of ladle de-

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[12] Wulpi, Donald J. A Consumer Looks at Continuously Cast Steel. Metal Prog., v. 86, No. 6, December 1964, pp. 72–77.

[13] Blast Furnace & Steel Plant. V. 52, No. 12, December 1964, p. 1175.

[14] Carlson, E. A., II. Description of the Controlled Pressure Pouring Plant at Eastern Stainless Steel Corp. Blast Furnace & Steel Plant, v. 52, No. 12, December 1964, pp. 1134–1136.

Fitch, T. S. Description of the Controlled Pressure Pouring Plant of Washington Steel Corp. Blast Furnace & Steel Plant, v. 52, No. 12, December 1964, pp. 1132–1134.

Fitch, T. S., and L. H. Wilson. The Controlled Pressure Pouring Process for Producing Slabs and Certain Cast Products. Iron and Steel Eng., v. 41, No. 12, December, 1964, pp. 69–85.

Mandich, L. I. Alloy Plates From Pressure Poured Slabs Vacuum Degassed and Non-Vacuum Degassed Electric Furnace Steel. Blast Furnace & Steel Plant, v. 52, No. 12, December 1964, pp. 1131–1132.

Woodburn, J., G. R. Lohman, and R. J. Nylen. Pressure Pouring Steel Slabs. J. Metals., v. 16, No. 12, December 1964, pp. 967–971.

[15] Weymueller, Carl, R. Vacuum Degassing: Key to Better Steels. Metal. Prog., v. 86, No. 3, September 1964, pp. 74–80.

TABLE 19.—Companies using vacuum degassing

Company	Type
Forging:	
Bethlehem Steel Corp.: Bethlehem, Pa.	Stream.
Cameron Iron Works Inc.: Houston, Tex.	Ladle (Finkl).
Erie Forge & Steel Corp.: Erie, Pa.	Stream.
A. Finkl & Sons Co.: Chicago, Ill.	Ladle (Finkl).
Isaacson Iron Works: Seattle, Wash.	Stream.
Mesta Machine Co.: Pittsburgh, Pa.	Do.
Midvale-Heppenstall Co.:	
Philadelphia, Pa.	Do.
Philadelphia, Pa.	Stream—tap.
National Forge Co.: Irvine, Pa.	D-H ladle.
Ohio Steel Foundry Co.: Lima, Ohio.	Stream.
Standard Steel Works Div.:	
Baldwin-Lima-Hamilton Corp., Burnham, Pa.	Do.
United States Steel Corp.: Duquesne, Pa.	Do.
Specialty steels:	
Allegheny Ludlum Steel Corp., Pittsburgh, Pa.	Pilot.
Armco Steel Corp.:	
Torrance, Calif.	Stream.
Butler, Pa.	
The Babcock & Wilcox Co.: Beaver Falls, Pa.	Stokes ladle.
Bethlehem Steel Corp.: Bethlehem, Pa.	Stream.
The Carpenter Steel Co.: Bridgeport, Conn.	D-H ladle.
Specialty Steels—Continued	
Copperweld Steel Co.:	
Warren, Ohio	D-H ladle.
Warren, Ohio	D-H ladle.[1]
Crucible Steel Co. of America: Midland, Pa.	D-H ladle.
Jones & Laughlin Steel Corp.: Detroit, Mich.	Do.
Republic Steel Corp.: Canton, Ohio.	Ladle—Induction stirred.
Sharon Steel Corp.: Sharon, Pa.	Stream.
The Timken Roller Bearing Co.:	
Canton, Ohio	D-H ladle.
Canton, Ohio	Do.
United States Steel Corp.:	
Homestead, Pa.	Stream.
Duquesne, Pa.	Do.
Universal-Cyclops Steel Corp.: Bridgeville, Pa.	Do.
General:	
Bethlehem Steel Corp.:	
Lackawanna, N.Y.	D-H ladle.
Bethlehem, Pa.	Stream.
Bethlehem, Pa.	R-H ladle.
Jones & Laughlin Steel Corp.: Pittsburgh, Pa.	D-H ladle.
Lukens Steel Co.: Coatesville, Pa.	D-H ladle.[1]
National Steel Corp.:	
Weirton, W. Va.	D-H ladle.
Weirton, W. Va.	(1).
Republic Steel Corp.: Chicago, Ill.	Ladle.
United States Steel Corp.:	
Gary, Ind.	(1).
Chicago, Ill.	Stream.

[1] Vacuum degassing units to be used with continuous casting.

gassing the ladle is mounted on a car at the melt shop and is moved through the vacuum chamber on a track, with 90 to 100 ton heats degassed in from 15 to 30 minutes at vacuums approaching 50 microns.[16]

Basic Oxygen Converters.—Production of steel in basic oxygen converters rose from 8.5 million tons in 1963 to 15.4 million tons in 1964. With planned additional capacity of 5 million, 8 million, and 6 million tons in 1964, 1965, and 1966, respectively, the production of steel in basic oxygen converters will continue to increase rapidly. The trend is not only toward more oxygen converter steels but toward larger oxygen converters. Vessels of 60- and 75-ton capacity were installed in the late 1950's. In the 1960's most of the furnaces range from 220 to 300 tons.

Bethlehem Steel put two 250-ton capacity converters into operation at the Lackawanna, N.Y., works, and each was producing 275 tons after about 1 month of operation. The 2 converters replaced an open hearth shop with 14 furnaces. The unit is highly automated; a General Electric 412 core-drum process computer is used. It is designed to calculate the charge, the alloy addition, and any corrective action after analysis. It should control the lance position, the oxygen flow and any additions to the converter other than hot metal and scrap. These furnaces have a height-to-diameter ratio of 1½ to 1.[17]

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[16] Iron & Steel Engineer. Car-Type Vacuum Degassing Unit Goes On-Line. V. 41, No. 10, October 1964, p. 170.

The Wisconsin Steel works of International Harvester Co. has completed a "start up" period of basic oxygen steelmaking. The oxygen shop contains two 120-ton-per-hour capacity furnaces. These 2 furnaces, capable of producing more than 1 million tons of ingots annually, will replace 11 open hearth furnaces. It is planned to add additional modernization facilities including continuous casting and vacuum degassing.

The oxygen steel plant at the Duquesne Works of the United States Steel Corp. consists of two 150-ton converters. These furnaces were being tested during the first part of 1964. They are now producing mostly silicon steels.[18]

The oxygen steelmaking furnaces to be built at the Republic Steel Corp.'s Cleveland district steel plant are 220-ton converters. Republic is also installing two 150-ton furnaces at its Warren, Ohio, plant, and two 150-ton furnaces at its Gadsden, Ala., plant. The converters at the Cleveland plant will eventually replace the No. 1 open-hearth shop. Three of the six open hearths in the No. 2 shop are using roof lances to furnish oxygen.

The Henry J. Kaiser Co., together with Brassert Oxygen Technik, A.G. (BOT) and VOEST, in a suit against the McLouth Steel Corp., is claiming that McLouth is infringing on patents for the Suess process with its oxygen steelmaking. Theodore Suess was a German steel expert who developed this process while working for VOEST.

Wheeling Steel Corp. has ordered an advanced control system for its oxygen steelmaking plant in Mingo Junction, Ohio.[19]

Charging a 70-ton electric arc furnace with hot metal from a 70-ton LD furnace is the complete switch being utilized by Société des Aciéries de Pompey in France. Duplexing takes care of the intermediate carbon and alloy grades in the company's steelmaking program.

United States Steel Corp. has made 80 different kinds of steel in its oxygen vessels at the Duquesne works.[20]

The Bureau of Mines continues to probe for the causes of fuming in the basic oxygen converters and to seek methods of reducing or containing these fumes.

In one of the first reported overhauls of a converter vessel the Colorado Fuel and Iron Corp. saved a good furnace bottom and stopped the harmful warping of a trunnion ring. First, a bottom which did not need repair was removed from a vessel at the trunnion ring and a newly fabricated top put in its place; then the furnace was reversed, the old top cut out and the bottom which had been removed from the other side put in place of the wornout top. This saved a complete rebuilding and, in fact, reversed the position of the trunnion ring 180° so that a deflection which was putting the ring out of position is now bringing it back into good horizontal position.[21]

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[17] Steel. Planning Smooths Startup of BOF's. V. 155, No. 21, Nov. 23, 1964, pp. 108, 110.

[18] Blast Furnace & Steel Plant. OSM Shop Is Important Addition in Duquesne Works Expansion. V. 52. No. 8, August 1964, pp. 719–721.

[19] Blast Furnace & Steel Plant. V. 52, No. 8. August 1964, p. 734.

[20] American Metal Market. V. 71, No. 97, May 19, 1964, p. 4.

[21] Iron and Steel Engineer. Operation Bottoms Up. V. 41, No. 4, April 1964, pp. 152–154.

End-point carbon control is determined by the use of two different methods of effluent gas analysis. One method is to test for percentage of oxygen in the waste gases in the hood draft above the mouth of the oxygen furnace; another method is the calculation of the end point based upon infrared analysis of the amount of waste CO_2 gas. The latter is similar to studies conducted by IRSID in France.[22]

A pyrometric detector tube containing a platinum-rhodium-18 thermocouple has been developed for continuous temperature measurement in the bath of LD and LDAC furnaces. Numerous tests in vessels ranging from one-fourth to 80 tons have demonstrated that this device accurately measures bath temperature when positioned properly with regard to bath height. This continuous temperature measurement not only makes it possible to take suitable corrective action during the blowing of heat, but it gives a valuable permanent record of the course of every melt. It also offers many possibilities for the eventual automatic control of the basic oxygen process.[23]

Another good discussion of the thermal balance in an oxygen converter and the problems of accuracy in determining the CO to CO_2 ratio is discussed in a paper on the LD plant of Hoogovens.[24]

Over 200 billion cubic feet of oxygen were consumed in 1964. The rapidly increasing use of oxygen by steelmakers is responsible for much of this phenomenal growth, since the industry consumes over 60 percent of the total oxygen output.

A measure of the huge growth in the amount of oxygen used in steelmaking can be gained from the knowledge that United States Steel Corp. has awarded a contract to provide 1,260 tons of high-purity oxygen and 520 tons of high-purity nitrogen per day at their Gary, Ind., works.

A third "Kaldo" oxygen furnace will be added by Sharon Steel Corp. to nearly double its present capacity of 1 million tons of steel ingot per year. Sharon is operating the only two Kaldo steelmaking units presently installed in the United States. After initial difficulties with refractories, Sharon now is averaging 120 heats per furnace lining and using a 50–50 ratio of scrap and hot metal. Further installations in the modernization program are a second vacuum degassing unit and a pressure pouring installation.

Electric Furnaces.—Over 60 percent of the output of electric furnaces in 1964 consisted of carbon steels. Electric furnaces are thus being shifted from the traditional use for high-alloy specialty steels. From 1950 to 1960 the increase in electric steel output was slow and uneven, but since 1960 the increase has been steadier and more rapid. The advent of the much more spectacular basic oxygen converter may well be a decisive factor in the complete acceptance of the electric furnace. The reduced scrap consumption of the basic oxygen converter has highlighted the need for better prepared scrap and the availability of a larger supply. An oversupply of scrap helps to maintain a firm

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[22] Iron and Steel Engineer. Continuous Determination of Bath Carbon in the Basic Oxygen Process. V. 41, No. 10, October 1964, pp. 67–71.
Journal of Metals. Effluent Gas Analysis for End-Point Carbon Control. V. 16, No. 9, September 1964, pp. 715–717.

[23] Journal of Metals. Continuous Temperature Measurement for Basic Oxygen Steelmaking. V. 16, No. 6, June 1964, pp. 483, 484.

[24] Steel Times (London). Assessment of the Limitations of Computer Control of the LD Process. V. 190, No. 5035, Jan. 15, 1965, pp. 82–87.

TABLE 20.—Chemical and physical characteristics of converter linings

	Working lining: tempered tar-bonded dolomite	Permanent lining: burnt tar-impregnated dolomite
Chemical analysis:		
MgO percent	35	35
CaO do	56	56
Fe_2O_3 do	.3	.8
SiO_2 do	.9	.9
Al_2O_3 do	.3	.8
Ignition loss (tar) do	6.5	6.5
Bulk density kg./cu. cm	2.8	2.8
Porosity volume-percent	11	15
Cold crushing strength at 20° C kg./sq. cm	180	450
Refractoriness under load at 2 kg./sq. cm:		
t_A °C	1,720	1,760
t_E °C	>1,800	>1,800
Thermal conductivity, kcal/mm °C:		
At 500° C	2.8	2.8
At 800° C	2.6	2.6
At 1,000° C	2.3	2.3
Storability:		
Winter days	35	100
Summer do	20	60

price structure and gives the electric furnace a cost advantage. The electric furnace shares with the oxygen converter the advantage of extreme flexibility of operation and apparently surpasses it in regard to reduced capital cost.

Estimates as to the optimum size for the electric furnace still vary considerably, although the average size is gradually increasing. The rated output of most electric furnaces in the United States is under 200 tons, but there are several furnaces in Japan and Europe rated over a 200-ton capacity. The advent of the basic oxygen converter also forced a realistic assessment of furnace capabilities. Careful programing of the charging, adapting operation to the electrical characteristics, and even installation of fume collection systems, are factors that have increased production.[25]

Lukens Steel Co. has put an IBM Operator Guide Control System into operation with its two 100-ton electric furnaces, operated in connection with a 150-ton vacuum degassing facility. In England BISRA has developed an automatic input control for use on electric arc furnaces.[26]

Latrobe Steel Co. has installed a 30-ton vacuum induction furnace in connection with its 30-ton electric furnaces. The induction furnace is charged with hot metal which permits stream degassing as the furnace is being charged, then induction heating and magnetic stirring continues under a higher vacuum. Bulk additions of alloys may be added and ingots cast, still within the vacuum. Heats are generally finished at a vacuum of about 5 microns.[27]

Carpenter Steel Co. has added a vacuum induction furnace at its Carpenter works in Reading, Pa. This unit is capable of 7.5 to 10 tons per heat with ingots being cast in vacuum.

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[25] Journal of Metals. Arc Furnace Steel Production, Kansas City Works—Armco Steel Corp. V. 16, No. 12, December 1964, pp. 1005–1012.

[26] Metcalf, A. Automatic Power Input Control for Arc Furnaces. Steel Times (London). V. 188, No. 4982, Jan. 10, 1964, pp. 50–52.

[27] Blast Furnace & Steel Plant. New Vacuum Melt Shop Unveiled. V. 52, No. 8, August 1964, pp. 716–718.

Introduction of oxygen lancing into the open hearth has reduced the time for completion of heats of steel and at the same time intensified the need for more rapid and more accurate determinations of carbon in the heat. More accurate and faster sampling of the steel and development of methods of indirectly analyzing the amount of carbon by the ratio of oxygen and carbon dioxide in the effluent gas have been attempted.[28]

As operating times in the open hearth are shortened, the need and advantage of automatic over manual combustion control becomes apparent. Comparison of the performance of furnaces with and without controllers in one shop indicated that the introduction of automatic combustion control resulted in a 6-percent decrease in the fuel consumption, a 33-percent decrease in basic brick consumption, and a nearly 5-percent increase in production rate.[29]

The Bureau of Mines continued research using mathematical techniques to work out the reactions involved with changing variables in blast furnace operation.

Nuclear measuring techniques are being developed to aid the operation of the blast furnace. The use of the continuous immersion thermocouple to aid temperature control in the blast furnace has been reported.[30]

A technique to get more representative samples of the hot metal coming from the blast furnace, which in turn would give the open-hearth operator a much more accurate picture of the silicon analysis, has been developed. Dip sampling of the pugh ladle is more representative than runner sampling and is good for both basic and merchant iron with a high degree of accuracy in either case. It is practical for everyday use. Pins from these dip samples can be analyzed spectrographically in much shorter time than by chemical analysis.[31]

"Caroline," a high-pressure, high-temperature experimental blast furnace operated by the Bureau of Mines at Bruceton, Pa., was blown in during April 1964. Operation of Caroline is supported by the appropriations of the Bureau of Mines and by Blast Furnace Research, Inc., a nonprofit organization representing 22 ironmaking companies in the United States and Canada.

Research continued by Bureau of Mines on the extent to which highly reduced iron pellets may be used as feed in steelmaking furnaces.

Automation, or automatic control, of various parts of the steelmaking process traditionally has centered on the rolling mill. As computers begin to be designed into the entire steelmaking operation, it has been difficult to design instrumentation rugged enough for monitoring at steelmaking temperatures to furnish data precise enough to take advantage of the computer's speed. However, it is now possible to have a certain amount of automatic control from the charging of the blast furnace, through basic oxygen converter steelmaking with the steel continuously cast and automatically rolled.[32]

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[28] Journal of Metals. Rapid Carbon Determination for Open-Hearth Control. V. 16, No. 2, February 1964, pp. 165–169.

[29] Iron and Steel Engineer. Combustion Control in the Open Hearth. V. 41, No. 6, June 1964, pp. 109–115.

[30] Blast Furnace & Steel Plant. Nuclear Applications in Coke Plant and Blast Furnace Operations. V. 52, No. 7, July 1964, pp. 611–620.
Iron and Steel Engineer. Continuous Immersion Thermocouple Aids Blast Furnace Control. V. 41, No. 7, July 1964, pp. 179–186.

[31] Smith, Phillip H. An Improved Technique for Sampling Blast Furnace Hot Metal. Blast Furnace & Steel Plant, v. 52, No. 9, September 1964, pp. 825–833, 880.

National Steel Corp. plans the first completely new steelmaking facility in this country to take advantage of basic oxygen furnaces, vacuum degassing, and continuous casting. This new unit will be at the company's Weirton Steel division.

A new steelmaking facility called the dual-hearth, or tandem hearth furnace, has been announced both here and South Africa. The furnace is essentially two identical interconnected hearths in which cold scrap in one hearth acts as a regenerator taking maximum advantage of the sensible heat of the waste gases being generated by the steelmaking in the other hearth. Efficiency of the heat transfer is greater. Because of alternating overlappinng functions the furnace does not lose heat, but stays alive.[33] The unlimited flexibility of the hot metal to scrap ratio up to 100-percent cold scrap charge reduces raw material expense.

Refractories.—Newer, better refractories are being developed to withstand the increased heat and pressure resulting from the introduction of oxygen. Basic materials are principally alumina and magnesia. Better chemistry, better material processing, and higher component purity have combined to raise the temperature threshold and provide special characteristics such as resistance to reduction in dry hydrogen atmospheres.[34]

Rolling mills are increasing in size, speed, and accuracy. Sharon Steel Corp. installed a 60-inch Sendzimir mill with a 3,500-hp. main drive. The mill operates at 2,000 feet per minute with a threading pass of 900 feet per minute.[35]

Width gages that work on a shadow technique and thickness gages that employ either X-ray or isotope exciting are only now being introduced in the United States, although there are several in use in Europe.[36]

High-velocity compacting of iron powders gives near theoretical densities for the resulting parts. If this is preceded by sintering, the part has higher strength and ductility than with ordinary compacting.[37]

Electroplating a steel slab 4 to 6 inches thick with a thick coating of nickel and then hot rolling the sandwich gives a pore-free nickel cladding which can be fabricated by everyday metalworking processes. A 6-inch steel core clad with an 0.060-inch layer of nickel is rolled to a ½-inch core with an 0.005-inch nickel skin. Another big advantage is that costs are said to be cut 50 percent.[38]

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[32] Iron Age. Automation: A Tough Taskmaster Bears Down on Instrumentation. V. 194, No. 5, July 30, 1964, pp. 60–62.

[33] Holz, Peter. Tandem Furnace Is Innovation in South African—Iscor-Steel Co. Blast Furnace & Steel Plant, v. 52, No. 4, April 1964, pp. 322–323, 349.

Mathias, W. M. The Dual-Hearth Furnace—The Most Versatile Tool in Modern Steelmaking. Iron and Steel Eng., v. 41, No. 12, December 1964, pp. 93–100.

[34] Birch, R. E. The Future Refractories and Steelmaking. J. Metals, v. 16, No. 6, June 1964, pp. 512–515.

Iron and Steel Engineer. Insulating Firebrick Developed for 2800° F. 100 Percent Dry Hydrogen Service. V. 41, No. 6, June 1964, pp. 183–184.

[35] Beck, A. J. Sharon Steel's 60-inch Sendzimir Mill Has 3,500 HP Main Drive. Iron and Steel Eng., v. 41, No. 12, December 1964, pp. 185–188.

[36] Iron and Steel Engineer. Precision Gaging Strip Width and Thickness. V. 41, No. 12, December 1964, pp. 129–134.

[37] Stein, Eugene M., John R. Van Orsdel, and Peter V. Schneider. High Velocity Compaction of Iron Powder. Metal Prog., v. 85, No. 4, April 1964, pp. 83–87.

[38] Iron Age. Plating Teams Up With Rolling To Clad Nickel Into Steel. V. 193, No. 22, May 28, 1964, pp. 63–65.

Nondestructive testing, and nondestructive testing during operation, is becoming necessary. The combination of an electron microscope and an X-ray microanalyzer coupled with a computerlike device that works off the microanalyzer has reduced rejection of steel tubes some 90 percent, according to the Tube Investment Research Laboratories (TIRL), an English firm. An optical emission spectrometer, combined with a pneumatic tube system for sending samples and returning analyses, can return a typewritten analysis of a melt to the operator in less than 9 minutes, giving a record of 11 major and minor elements. It can detect boron, for instance, down to 0.0005 percent. It may soon be possible to examine the crystalline structure of steel with ultrasonic spectroscopy. With this type of examination, heat treating could be much more meaningful. Electromagnetic, ultrasonic, and X-ray techniques are being improved and combined. The use of the X-ray fluoroscope on welds is being refined. Eddy currents are used to inspect pipe welds in continuous welding mills. An infrared detector can measure the thickness of hot steel plates to an accuracy of 0.002 inch, making the check every 8 inches on steel products going through rolling mills at 70 miles per hour.

The ability to predict the characteristics of compounds or alloys of all 33 metallic elements when mixed in all of their billions of possible combinations may be the outcome of a new theory known as the electron theory of crystal structure. Described as the most important new idea to come out of the materials field in the past decade, the theory was developed by Brewer of the University of California. Researchers should be able to seek new materials in the transition series systematically and comprehensively. In developing his theory Brewer says that he combined Engle's theory (the correlation between electronic configurations and crystal structures of metallic phases) with known information about the sizes of atoms, predictions of their solubility, and the effects of heat on various combinations and ratios of the metals. He has considered temperatures up to the melting points.[39]

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[39] Product Engineering. V. 35, No. 15, July 20, 1964, pp. 63–64.

Iron and Steel Scrap

By Robert A. Whitman [1]

◆

TOTAL SCRAP used in the basic oxygen converters nearly doubled in 1964. For the second year the total consumption of scrap increased 13 percent. The year was marked by increased automation of the processing of scrap, widespread attention directed to the waste of ferrous scrap in auto junkyards, and the continued testing and development of methods to increase the use of scrap in steelmaking.

TABLE 1.—Salient iron and steel scrap, and pig iron statistics in the United States

(Short tons)

	1963	1964
Stocks Dec. 31:		
Scrap at consumer plants	r 7,945,286	7,413,013
Pig iron at consumer and supplier plants	r 2,805,986	2,461,406
Total	10,751,272	9,874,419
Consumption:		
Scrap	74,620,730	84,625,664
Pig iron	72,688,740	86,381,699
Imports for consumption, scrap (including tinplate scrap)	217,207	281,689
Exports, iron and steel scrap	6,363,617	7,886,469
Price: Scrap, No. 1 heavy-melting, Pittsburgh, average—per long ton [1]	r $26.58	$34.18
Value: Scrap, all grades, for export [2]	$30.73	$34.53

r Revised.
[1] Iron Age.
[2] As computed from export data obtained from the Bureau of the Census.

It was significant that, while there has been a shift in steelmaking to basic oxygen converters which use less scrap than open-hearth furnaces, there was 2.5 percent more scrap in the total metallics charged into oxygen furnaces during 1964. Steelmaking furnaces consumed 76 percent of all scrap used, the same as in 1963. The percentage of total scrap used in steelmaking furnaces has varied only about 1 percent since 1955. Fourth quarter consumption was the largest in 1964, over 22 million tons, and 77 percent of this scrap was consumed by steelmaking furnaces. Steelmakers were not buying No. 2 bundles which are made from junk auto bodies. The background of the scrap automobile problem was well presented to over 100 representatives of the Federal Government and of city, county, and State governments at the National Conference on Auto Salvage sponsored by the Institute of Scrap Iron and Steel, Inc., in Washington, D.C., on October 1.

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[1] Commodity specialist, Division of Minerals

Legislation and Government Programs.—Public Law 88–324 extended for 1 year from July 1, 1964, the suspension of duties on the imports of scrap metal.

The U.S. Maritime Commission disposed of 133 ships, 91 Liberty ships and 42 other World War II ships, through 25 sales proposals to shipbreakers in the United States.

AVAILABLE SUPPLY

The increase of 10 million tons of new iron and steel scrap available in 1964 nearly equaled the increase in total consumption. The supply of home scrap rose 17 percent, reflecting the large increase in steel production. There was 14 percent more scrap available from dealers and other sources in 1964. The data in table 2 exclude scrap on hand in dealers' yards.

TABLE 2.—Iron and steel scrap supply[1] available for consumption in 1964, by districts and States

(Short tons)

District and State	Home production	Receipts from dealers and all others	Total new supply	Shipments[2]	New supply available for consumption
New England:					
Connecticut	88, 881	99, 019	187, 900	6, 546	181, 354
Maine and New Hampshire	4, 792	9, 167	13, 959	487	13, 472
Massachusetts	84, 102	116, 645	200, 747	4, 199	196, 548
Rhode Island	41, 088	65, 324	106, 412	2, 954	103, 458
Vermont	9, 014	13, 852	22, 866	110	22, 756
Total:					
1964	227, 877	304, 007	531, 884	14, 296	517, 588
1963	205, 793	276, 282	482, 075	15, 006	467, 069
Middle Atlantic:					
New Jersey	222, 387	570, 380	792, 767	18, 083	774, 684
New York	2, 305, 524	1, 271, 487	3, 577, 011	87, 595	3, 489, 416
Pennsylvania	11, 591, 008	6, 232, 748	17, 823, 756	1, 506, 204	16, 317, 552
Total:					
1964	14, 118, 919	8, 074, 615	22, 193, 534	1, 611, 882	20, 581, 652
1963	11, 803, 233	6, 416, 785	18, 220, 018	575, 711	17, 644, 307
East North Central:					
Illinois	4, 673, 002	4, 214, 174	8, 887, 176	211, 542	8, 675, 634
Indiana	6, 743, 545	3, 489, 443	10, 232, 988	520, 019	9, 712, 969
Michigan	4, 223, 778	4, 159, 164	8, 382, 942	64, 455	8, 318, 487
Ohio	9, 725, 723	6, 000, 392	15, 726, 115	1, 261, 015	14, 465, 100
Wisconsin	614, 083	522, 128	1, 136, 211	108, 263	1, 027, 948
Total:					
1964	25, 980, 131	18, 385, 301	44, 365, 432	2, 165, 294	42, 200, 138
1963	22, 586, 915	16, 405, 039	38, 991, 954	1, 387, 472	37, 604, 482

See footnotes at end of table.

TABLE 2.—Iron and steel scrap supply[1] available for consumption in 1964, by districts and States—Continued

(Short tons)

District and State	Home production	Receipts from dealers and all others	Total new supply	Shipments[2]	New supply available for consumption
West North Central:					
Iowa	210,134	369,312	579,446	3,706	575,740
Kansas and Nebraska	50,948	94,741	145,689	4,483	141,206
Minnesota	266,678	212,457	479,135	10,574	468,561
Missouri	249,763	716,876	966,639	8,540	958,099
Total:					
1964	777,523	1,393,386	2,170,909	27,303	2,143,606
1963	714,754	1,378,850	2,093,604	40,677	2,052,927
South Atlantic:					
Delaware and Maryland	3,197,580	466,775	3,664,355	267,522	3,396,833
Florida and Georgia	114,013	357,471	471,484	1,512	469,972
North Carolina	24,252	68,437	92,689	3,585	89,104
South Carolina	17,921	27,500	45,421		45,421
Virginia and West Virginia	931,206	1,144,523	2,075,729	7,099	2,068,630
Total:					
1964	4,284,972	2,064,706	6,349,678	279,718	6,069,960
1963	3,525,346	1,921,144	5,446,490	202,949	5,243,541
East South Central:					
Alabama	1,721,888	1,432,116	3,154,004	147,855	3,006,149
Kentucky, Mississippi, Tennessee	934,717	1,222,680	2,157,397	80,974	2,076,423
Total:					
1964	2,656,605	2,654,796	5,311,401	228,829	5,082,572
1963	2,264,341	2,483,302	4,747,643	263,889	4,483,754
West South Central:					
Arkansas, Louisiana, Oklahoma	61,292	184,399	245,691	3,148	242,543
Texas	1,105,145	959,673	2,064,818	82,003	1,982,815
Total:					
1964	1,166,437	1,144,072	2,310,509	85,151	2,225,358
1963	882,610	1,038,477	1,921,087	41,147	1,879,940
Rocky Mountain:					
Arizona and Nevada	35,433	159,827	195,260	877	194,383
Colorado, Idaho, Montana, Utah	1,349,391	450,341	1,799,732	33,017	1,766,715
Total:					
1964	1,384,824	610,168	1,994,992	33,894	1,961,098
1963	1,137,998	699,681	1,837,679	45,677	1,792,002
Pacific Coast:					
California and Hawaii	1,511,848	1,516,759	3,028,607	376,119	2,652,488
Oregon and Washington	153,190	516,457	669,647	10,716	658,931
Total:					
1964	1,665,038	2,033,216	3,698,254	386,835	3,311,419
1963	1,533,743	1,627,987	3,161,730	243,328	2,918,402
U.S. total:					
1964	52,262,326	36,664,267	88,926,593	4,833,202	84,093,391
1963	44,654,733	32,247,547	76,902,280	2,815,856	74,086,424

[1] New supply available for consumption is a net figure computed by adding home production to receipts from dealers and all others and deducting consumers scrap shipped, transferred, or otherwise disposed of during the year. The plus or minus difference in stock levels at the beginning and end of the year are not taken into consideration.

[2] Includes scrap shipped, transferred, or otherwise disposed of during the year.

TABLE 3.—Consumption of iron and steel scrap and pig iron in the United States in 1964, by type of consumer and type of furnace or equipment

(Short tons)

Type of furnace or equipment	Type of consumer		
	Scrap	Pig iron [1]	Total
	Manufacturers of steel ingots and castings [2]		
Open-hearth	43, 127, 449	65, 115, 381	108, 242, 830
Basic oxygen converter [3]	5, 485, 926	12, 445, 550	17, 931, 476
Bessemer	59, 082	934, 809	993, 891
Electric [4]	12, 450, 504	252, 084	12, 702, 588
Total steelmaking furnaces	61, 122, 961	78, 747, 824	139, 870, 785
Cupola	1, 230, 100	330, 836	1, 560, 936
Air	43, 782	11, 306	55, 088
Blast [5]	4, 815, 668	-----	4, 815, 668
Direct castings	-----	2, 938, 355	2, 938, 355
Miscellaneous	58, 773	-----	58, 773
Total:			
1964	67, 271, 284	82, 028, 321	149, 299, 605
1963	59, 291, 199	68, 589, 146	127, 880, 345
	Manufacturers of steel castings [6]		
Open-hearth	753, 932	90, 870	844, 802
Bessemer	10, 425	132	10, 557
Electric	2, 191, 808	38, 125	2, 229, 933
Total steelmaking furnaces	2, 956, 165	129, 127	3, 085, 292
Cupola	340, 391	17, 902	358, 293
Air	230, 494	44, 993	275, 487
Total:			
1964	3, 527, 050	192, 022	3, 719, 072
1963	3, 053, 696	170, 169	3, 223, 865
	Iron foundries and miscellaneous users		
Bessemer	49, 101	13, 592	62, 693
Electric [4]	219, 640	34, 911	254, 551
Total steelmaking furnaces	268, 741	48, 503	317, 244
Cupola	11, 836, 952	3, 355, 745	15, 192, 697
Air	1, 166, 776	113, 658	1, 280, 434
Direct castings	-----	643, 450	643, 450
Ferroalloy	411, 800	-----	411, 800
Miscellaneous	143, 061	-----	143, 061
Total:			
1964	13, 827, 330	4, 161, 356	17, 988, 686
1963	12, 275, 835	3, 929, 425	16, 205, 260
	Total		
Open-hearth	43, 881, 381	65, 206, 251	109, 087, 632
Basic oxygen converter [3]	5, 485, 926	12, 445, 550	17, 931, 476
Bessemer	118, 608	948, 533	1, 067, 141
Electric [4]	14, 861, 952	325, 120	15, 187, 072
Total steelmaking furnaces	64, 347, 867	78, 925, 454	143, 273, 321
Cupola	13, 407, 443	3, 704, 483	17, 111, 926
Air	1, 441, 052	169, 957	1, 611, 009
Blast [5]	4, 815, 668	-----	4, 815, 668
Direct castings	-----	3, 581, 805	3, 581, 805
Ferroalloy	411, 800	-----	411, 800
Miscellaneous	201, 834	-----	201, 834
Total:			
1964	84, 625, 664	86, 381, 699	171, 007, 363
1963	74, 620, 730	72, 688, 740	147, 309, 470

[1] Includes molten metal.
[2] Includes only these castings made by companies producing steel ingots.
[3] Includes scrap and pig iron processed in metallurgical blast cupola and used in oxygen converters.
[4] Includes small quantities of scrap and pig iron consumed in crucible furnaces and vacuum melting.
[5] Includes consumption in all blast furnaces producing pig iron.
[6] Excludes companies that produce both steel ingots and steel castings.

TABLE 4.—Proportion of iron and steel scrap and pig iron used in furnaces in the United States

(Percent)

Type of furnace	1963		1964	
	Scrap	Pig iron	Scrap	Pig iron
Open-hearth	[r]41.3	[r]58.7	40.2	59.8
Basic oxygen converter	28.2	71.8	30.6	69.4
Bessemer	[r]10.4	[r]89.6	11.1	88.9
Electric [1]	98.4	1.6	97.9	2.1
Cupola	76.8	23.2	78.4	21.6
Air	88.1	11.9	89.5	10.5

[r] Revised.
[1] Includes crucible furnaces and vacuum melting.

CONSUMPTION BY DISTRICTS AND STATES

Consumption of scrap increased in every district in 1964. The East North Central district had the largest increase in tonnage with 4.5 million short tons, while the Middle Atlantic and West South Central districts had increases of 17 and 18 percent, respectively. The Middle Atlantic and East North Central districts consumed 75 percent of the total scrap. The five principal consuming States, with their percentage use, were Pennsylvania, 20; Ohio, 17; Indiana, 11; Illinois and Michigan, 10 each.

TABLE 5.—Consumption of iron and steel scrap and pig iron in the United States in 1964, by districts and States

(Short tons)

District and State	Scrap	Pig iron	Total
New England:			
Connecticut	177,185	32,833	210,018
Maine and New Hampshire	13,223	1,999	15,222
Massachusetts	200,113	57,586	257,699
Rhode Island	104,316	42,408	146,724
Vermont	22,042	6,178	28,220
Total:			
1964	516,879	141,004	657,883
1963	462,581	130,248	592,829
Middle Atlantic:			
New Jersey	768,340	112,089	880,429
New York	3,352,625	4,606,010	7,958,635
Pennsylvania	16,657,651	21,373,302	38,030,953
Total:			
1964	20,778,616	26,091,401	46,870,017
1963	17,692,320	21,411,492	39,103,812
East North Central:			
Illinois	8,701,600	5,858,222	14,559,822
Indiana	9,576,031	11,367,746	20,943,777
Michigan	8,393,899	7,462,185	15,856,084
Ohio	14,623,262	15,092,990	29,716,252
Wisconsin	1,026,704	192,249	1,218,953
Total:			
1964	42,321,496	39,973,392	82,294,888
1963	37,858,535	33,963,552	71,822,087
West North Central:			
Iowa	572,584	88,128	660,712
Kansas and Nebraska	146,611	5,854	152,465
Minnesota	484,919	524,912	1,009,831
Missouri	1,028,858	39,687	1,068,545

TABLE 5.—Consumption of iron and steel scrap and pig iron in the United States in 1964, by districts and States—Continued

(Short tons)

District and State	Scrap	Pig iron	Total
Total:			
1964	2, 232, 972	658, 581	2, 891, 553
1963	2, 021, 760	568, 274	2, 590, 034
South Atlantic:			
Delaware and Maryland	3, 487, 975	5, 691, 698	9, 179, 673
Florida and Georgia	481, 400	13, 535	494, 935
North Carolina	91, 052	33, 246	124, 298
South Carolina	51, 794	16, 683	68, 477
Virginia and West Virginia	2, 035, 426	2, 375, 911	4, 411, 337
Total:			
1964	6, 147, 647	8, 131, 073	14, 278, 720
1963	5, 379, 790	7, 135, 217	12, 515, 007
East South Central:			
Alabama	3, 029, 877	3, 737, 824	6, 767, 701
Kentucky, Mississippi, Tennessee	2, 090, 002	1, 495, 872	3, 585, 874
Total:			
1964	5, 119, 879	5, 233, 696	10, 353, 575
1963	4, 484, 981	4, 391, 481	8, 876, 462
West South Central:			
Arkansas, Louisiana, Oklahoma	248, 107	12, 144	260, 251
Texas	2, 043, 986	1, 332, 816	3, 376, 802
Total:			
1964	2, 292, 093	1, 344, 960	3, 637, 053
1963	1, 943, 932	950, 417	2, 894, 349
Rocky Mountain:			
Arizona, Nevada, Colorado, Idaho, Montana, Utah	1, 969, 124	2, 510, 068	4, 479, 192
Total:			
1964	1, 969, 124	2, 510, 068	4, 479, 192
1963	1, 793, 534	2, 230, 593	4, 024, 127
Pacific Coast:			
California and Hawaii	2, 613, 334	2, 250, 640	4, 863, 974
Oregon and Washington	633, 624	46, 884	680, 508
Total:			
1964	3, 246, 958	2, 297, 524	5, 544, 482
1963	2, 983, 297	1, 907, 466	4, 890, 763
U.S. total:			
1964	84, 625, 664	86, 381, 699	171, 007, 363
1963	74, 620, 730	72, 688, 740	147, 309, 470

TABLE 6.—Consumption of iron and steel scrap and pig iron by districts and States, by type of manufacturers in 1964

(Short tons)

District and State	Steel ingots and castings [1]		Steel castings [2]		Iron foundries and miscellaneous users	
	Scrap	Pig iron	Scrap	Pig iron	Scrap	Pig iron
New England:						
Connecticut	58, 840		5, 736	213	112, 609	32, 620
Maine and New Hampshire			3, 259	121	9, 964	1, 878
Massachusetts			6, 626	348	193, 487	57, 238
Rhode Island	60, 461	28, 607			43, 855	13, 801
Vermont					22, 042	6, 178
Total:						
1964	119, 301	28, 607	15, 621	682	381, 957	111, 715
1963	105, 621	26, 217	13, 054	785	343, 906	103, 246

See footnotes at end of table.

TABLE 6.—Consumption of iron and steel scrap and pig iron by districts and States, by type of manufacturers in 1964—Continued

(Short tons)

District and State	Steel ingots and castings [1]		Steel castings [2]		Iron foundries and miscellaneous users	
	Scrap	Pig iron	Scrap	Pig iron	Scrap	Pig iron
Middle Atlantic:						
New Jersey	234,391	21,256	60,080	2,671	473,869	88,162
New York	2,494,618	4,420,371	185,521	11,558	672,486	174,081
Pennsylvania	15,392,065	21,140,202	488,055	40,665	777,531	192,435
Total:						
1964	18,121,074	25,581,829	733,656	54,894	1,923,886	454,678
1963	15,407,594	20,930,470	604,407	53,958	1,680,319	427,064
East North Central:						
Illinois	6,884,927	5,431,755	532,583	25,847	1,284,090	400,620
Indiana	8,699,726	11,148,819	206,763	6,811	669,542	212,116
Michigan	5,039,828	6,847,527	156,705	1,627	3,197,366	613,031
Ohio	12,558,447	14,358,942	466,048	68,876	1,598,767	665,172
Wisconsin	----------	----------	340,551	8,509	686,153	183,740
Total:						
1964	33,182,928	37,787,043	1,702,650	111,670	7,435,918	2,074,679
1963	29,753,571	31,974,923	1,518,450	91,044	6,586,514	1,897,585
West North Central:						
Iowa	----------	----------	45,022	358	527,562	87,770
Kansas and Nebraska	----------	----------	104,295	380	42,316	5,474
Minnesota	310,258	478,811	50,192	174	124,469	45,927
Missouri	782,371	5,303	120,125	7,785	126,362	26,599
Total:						
1964	1,092,629	484,114	319,634	8,697	820,709	165,770
1963	1,000,692	411,102	274,504	7,470	746,564	149,702
South Atlantic:						
Delaware and Maryland	3,363,183	5,681,835	34,937	666	89,855	9,197
Florida and Georgia	425,353	----------	14,864	91	41,183	13,444
North Carolina	----------	----------	(3)	----------	85,902	33,246
South Carolina	----------	----------	----------	----------	51,794	16,683
Virginia and West Virginia	1,610,353	2,250,006	79,977	5,625	350,246	120,280
Total:						
1964	5,398,889	7,931,841	129,778	6,382	618,980	192,850
1963	4,731,611	6,944,739	108,863	9,035	539,316	181,443
East South Central:						
Alabama	1,956,404	2,949,960	100,697	197	972,776	787,667
Kentucky, Mississippi, Tennessee	1,470,937	1,283,577	24,952	1,894	594,113	210,401
Total:						
1964	3,427,341	4,233,537	125,649	2,091	1,566,889	998,068
1963	3,002,607	3,383,782	80,756	1,664	1,401,618	1,006,035
West South Central:						
Arkansas, Louisiana, Oklahoma	130,769	----------	58,089	1,351	59,249	10,793
Texas	1,504,427	1,268,739	115,423	788	424,136	63,289
Total:						
1964	1,635,196	1,268,739	173,512	2,139	483,385	74,082
1963	1,373,998	874,402	156,942	1,495	412,992	74,520
Rocky Mountain:						
Arizona and Nevada	102,296	----------	61,779	87	28,479	----------
Colorado, Idaho, Montana, Utah	1,571,670	2,503,897	36,467	1,220	168,433	4,864
Total:						
1964	1,673,966	2,503,897	98,246	1,307	196,912	4,864
1963	1,522,348	2,224,066	85,801	927	185,385	5,600
Pacific Coast						
California and Hawaii	2,110,578	2,165,123	140,499	2,590	362,257	82,927
Oregon and Washington	509,382	43,591	87,805	1,570	36,437	1,723
Total:						
1964	2,619,960	2,208,714	228,304	4,160	398,694	84,650
1963	2,393,157	1,819,445	210,919	3,791	379,221	84,230
U.S. total:						
1964	67,318,690	82,041,661	3,527,050	192,022	13,779,924	4,148,016
1963	59,291,199	68,589,146	3,053,696	170,169	12,275,835	3,929,425

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[1] Includes only those castings made by companies producing steel ingots.
[2] Excludes companies that produce both steel ingots and steel castings.
[3] To avoid disclosure North Carolina included with Virginia and West Virginia.

TABLE 7.—Consumption of iron and steel scrap and pig iron in open-hearth furnaces in the United States in 1964, by districts and States

(Short tons)

District and State	Scrap	Pig iron	Total
New England and Middle Atlantic:			
New Jersey, New York, Rhode Island	2,274,139	3,965,384	6,239,523
Pennsylvania	10,259,114	16,478,501	26,737,615
Total:			
1964	12,533,253	20,443,885	32,977,138
1963[r]	11,240,903	18,281,511	29,522,414
East North Central:			
Illinois	4,120,408	4,872,018	8,992,426
Indiana	8,489,614	10,925,006	19,414,620
Michigan and Wisconsin	1,607,583	1,644,478	3,252,061
Ohio	7,519,508	11,897,315	19,416,823
Total:			
1964	21,737,113	29,338,817	51,075,930
1963	20,634,763	26,150,565	46,785,328
West North Central:			
Minnesota and Missouri	346,338	478,286	824,624
Total:			
1964	346,338	478,286	824,624
1963	330,228	414,858	745,086
South Atlantic:			
Delaware, Maryland, West Virginia	4,481,465	7,930,031	12,411,496
Total:			
1964	4,481,465	7,930,031	12,411,496
1963	3,970,967	6,946,690	10,917,657
East and West South Central:			
Alabama, Kentucky, Texas	2,764,624	4,403,005	7,167,629
Total:			
1964	2,764,624	4,403,005	7,167,629
1963	2,465,960	3,890,589	6,356,549
Rocky Mountain and Pacific Coast:			
California, Colorado, Utah	2,018,588	2,612,227	4,630,815
Total:			
1964	2,018,588	2,612,227	4,630,815
1963	2,029,016	2,150,690	4,179,706
U.S. total:			
1964	43,881,381	65,206,251	109,087,632
1963[r]	40,671,837	57,834,903	98,506,740

[r] Revised.

TABLE 8.—Consumption of iron and steel scrap and pig iron in Bessemer converters in the United States, by districts

(Short tons)

District	Scrap	Pig iron	Total
New England and Middle Atlantic:			
1964	52,909	152,487	205,396
1963	45,175	229,446	274,621
East North Central:			
1964	60,307	796,042	856,349
1963	72,486	830,149	902,635
West South Central and Rocky Mountain:			
1964	5,392	4	5,396
1963	5,053		5,053
U.S. total:			
1964	118,608	948,533	1,067,141
1963[r]	122,714	1,059,595	1,182,309

[r] Revised.

TABLE 9.—Consumption of iron and steel scrap and pig iron in electric[1] steel furnaces in the United States in 1964, by districts and States

(Short tons)

District and State	Scrap	Pig iron	Total
New England:			
Connecticut and New Hampshire	72,886	1,508	74,394
Massachusetts	8,786	825	9,611
Total:			
1964	81,672	2,333	84,005
1963	66,966	1,852	68,818
Middle Atlantic:			
New Jersey	58,358	1,817	60,175
New York	244,308	4,632	248,940
Pennsylvania	2,985,364	50,266	3,035,630
Total:			
1964	3,288,030	56,715	3,344,745
1963	2,745,881	49,246	2,795,127
East North Central:			
Illinois	2,123,698	22,328	2,146,026
Indiana	160,898	5,317	166,215
Michigan	600,745	5,322	606,067
Ohio	2,793,803	68,766	2,862,569
Wisconsin	245,926	5,709	251,635
Total:			
1964	5,925,070	107,442	6,032,512
1963	5,268,820	72,358	5,341,178
West North Central:			
Iowa, Kansas, Nebraska	152,858	828	153,686
Minnesota and Missouri	910,593	6,314	916,907
Total:			
1964	1,063,451	7,142	1,070,593
1963	909,865	3,452	913,317
South Atlantic:			
Delaware and Maryland	119,118	1,812	120,930
Florida, Georgia, North Carolina	443,590	458	444,048
Virginia and West Virginia	224,179	471	224,650
Total:			
1964	786,887	2,741	789,628
1963	617,204	1,930	619,134
East South Central:			
Alabama	611,926	50,254	662,180
Kentucky, Mississippi, Tennessee	568,014	909	568,923
Total:			
1964	1,179,940	51,163	1,231,103
1963	1,048,990	55,895	1,104,885
West South Central:			
Arkansas, Louisiana, Oklahoma	186,996	3,244	190,240
Texas	605,182	29,229	634,411
Total:			
1964	792,178	32,473	824,651
1963	768,398	8,639	777,037
Rocky Mountain:			
Arizona, Colorado, Nevada, Utah	187,766	717	188,483
Total:			
1964	187,766	717	188,483
1963	164,772	446	165,218
Pacific Coast:			
California and Hawaii	962,592	19,595	982,187
Oregon and Washington	594,366	44,799	639,165
Total:			
1964	1,556,958	64,394	1,621,352
1963	1,344,186	17,816	1,362,002
U.S. total:			
1964	14,861,952	325,120	15,187,072
1963	12,935,082	211,634	13,146,716

[1] Includes small quantities of scrap and pig iron consumed in crucible furnaces and vacuum melting.

TABLE 10.—Consumption of iron and steel scrap and pig iron in cupola furnaces in the United States in 1964, by districts and States

(Short tons)

District and State	Scrap	Pig iron	Total
New England:			
Connecticut	70, 728	24, 636	95, 364
Maine and New Hampshire	6, 813	314	7, 127
Massachusetts	187, 593	55, 061	242, 654
Rhode Island	35, 427	12, 807	48, 234
Vermont	22, 042	6, 178	28, 220
Total:			
1964	322, 603	98, 996	421, 599
1963	288, 864	91, 772	380, 636
Middle Atlantic:			
New Jersey	466, 294	88, 344	554, 638
New York	580, 675	166, 176	746, 851
Pennsylvania	607, 272	193, 845	801, 117
Total:			
1964	1, 654, 241	448, 365	2, 102, 606
1963	1, 446, 389	406, 195	1, 852, 584
East North Central:			
Illinois	1, 102, 115	185, 350	1, 287, 465
Indiana	620, 395	204, 875	825, 270
Michigan	3, 661, 967	644, 729	4, 306, 696
Ohio	1, 696, 868	365, 678	2, 062, 546
Wisconsin	610, 539	155, 970	766, 509
Total:			
1964	7, 691, 884	1, 556, 602	9, 248, 486
1963	6, 772, 582	1, 530, 513	8, 303, 095
West North Central:			
Iowa	379, 512	85, 664	465, 176
Kansas and Nebraska	42, 307	5, 474	47, 781
Minnesota	134, 632	42, 942	177, 574
Missouri	96, 101	24, 692	120, 793
Total:			
1964	652, 552	158, 772	811, 324
1963	625, 249	142, 539	767, 788
South Atlantic:			
Maryland	111, 700	10, 181	121, 881
Florida	8, 712	3, 232	11, 944
Georgia	30, 505	9, 884	40, 389
North Carolina	85, 665	33, 207	118, 872
South Carolina	41, 713	16, 683	58, 396
Virginia	307, 404	107, 271	414, 675
West Virginia	9, 696	10, 998	20, 694
Total:			
1964	595, 395	191, 456	786, 851
1963	540, 943	180, 465	721, 408
East South Central:			
Alabama	894, 223	793, 447	1, 687, 670
Kentucky	231, 434	55, 724	287, 158
Tennessee	305, 011	155, 662	460, 673
Total:			
1964	1, 430, 668	1, 004, 833	2, 435, 501
1963	1, 290, 366	1, 013, 124	2, 303, 490
West South Central:			
Louisiana and Oklahoma	56, 189	8, 900	65, 089
Texas	425, 367	118, 192	543, 559
Total:			
1964	481, 556	127, 092	608, 648
1963	408, 257	111, 556	519, 813
Rocky Mountain:			
Colorado, Montana, Utah	175, 444	35, 069	210, 513
Total:			
1964	175, 444	35, 069	210, 513
1963	169, 873	37, 204	207, 077

TABLE 10.—Consumption of iron and steel scrap and pig iron in cupola furnaces in the United States in 1964, by districts and States—Continued

(Short tons)

District and State	Scrap	Pig iron	Total
Pacific Coast:			
California	374,002	81,213	455,215
Oregon and Washington	29,098	2,085	31,183
Total:			
1964	403,100	83,298	486,398
1963	377,467	83,223	460,690
U.S. total:			
1964	13,407,443	3,704,483	17,111,926
1963	11,919,990	3,596,591	15,516,581

TABLE 11.—Consumption of iron and steel scrap and pig iron in air furnaces in the United States in 1964, by districts and States

(Short tons)

District and State	Scrap	Pig iron	Total
New England:			
Connecticut	35,078	6,678	41,756
Massachusetts, New Hampshire, Rhode Island	15,313	4,258	19,571
Total:			
1964	50,391	10,936	61,327
1963	48,709	10,336	59,045
Middle Atlantic:			
New Jersey and New York	28,212	9,853	38,065
Pennsylvania	186,981	39,785	226,766
Total:			
1964	215,193	49,638	264,831
1963	206,474	53,447	259,921
East North Central:			
Illinois	292,400	12,032	304,432
Indiana	69,146	12,274	81,420
Michigan	223,036	1,530	224,566
Ohio	380,266	40,889	421,155
Wisconsin	120,441	28,111	148,552
Total:			
1964	1,085,289	94,836	1,180,125
1963	979,546	98,704	1,078,250
West North Central:			
Iowa, Minnesota, Missouri	10,053	6,652	16,705
Total:			
1964	10,053	6,652	16,705
1963	10,404	7,290	17,694
South Atlantic:			
West Virginia	15,024	6,845	21,869
Total:			
1964	15,024	6,845	21,869
1963	10,870	6,132	17,002
East and West South Central:			
Alabama and Texas	62,779	919	63,698
Total:			
1964	62,779	919	63,698
1963	54,925	1,261	56,186
Pacific Coast:			
California	2,323	131	2,454
Total:			
1964	2,323	131	2,454
1963	6,318	359	6,677
U.S. total:			
1964	1,441,052	169,957	1,611,009
1963	1,317,246	177,529	1,494,775

TABLE 12.—Consumption of iron and steel scrap in blast furnaces in the United States in 1964, by districts and States

(Thousand short tons)

District and State	Scrap	District and State	Scrap
Middle Atlantic:		South Atlantic, East and West South Central:	
New York	250	Alabama	160
Pennsylvania	1,255	Kentucky, Maryland, Texas, West Virginia	375
Total:		Total:	
1964	1,505	1964	535
1963	1,440	1963 [1]	487
East and West North Central:		Rocky Mountain:	
Illinois	529	Colorado and Utah	217
Indiana	215	Total:	
Michigan and Minnesota	305	1964	217
Ohio	1,510	1963	136
Total:		U.S. total:	
1964	2,559	1964	4,816
1963	2,243	1963	4,306

[1] Includes Tennessee.

TABLE 13.—Consumption of iron and steel scrap by ferroalloy producers in the United States in 1964, by districts

(Short tons)

District	Scrap	District	Scrap
Middle Atlantic:			
1964	58,869	East South Central:	
1963	44,763	1964	100,482
East North Central:		1963	85,031
1964	79,282	Pacific Coast:	
1963	58,231	1964	9,583
West North Central:		1963	7,746
1964	143,810		
1963	129,669	U.S. total:	
South Atlantic:		1964	411,800
1964	19,774	1963	345,375
1963	19,935		

TABLE 14.—Consumption of iron and steel scrap in miscellaneous uses[1] in the United States in 1964, by districts and States

(Short tons)

District and State	Scrap
New England and Middle Atlantic:	
New York	19,070
New Jersey	40,293
Pennsylvania	1,472
Total:	
1964	60,835
1963	75,457
East North Central:	
Illinois, Indiana, and Michigan	34,654
Ohio	3,980
Total:	
1964	38,634
1963	51,200
West North Central: Minnesota and Missouri	13,055
Total:	
1964	13,055
1963	11,217
South Atlantic: Delaware, Florida, Georgia, and Virginia	5,552
Total:	
1964	5,552
1963	7,268
East and West South Central:	
Alabama and Texas	24,803
Total:	
1964	24,803
1963	10,646
Rocky Mountain: Arizona, Colorado, Idaho, Montana, Utah	37,368
Total:	
1964	37,368
1963	29,475
Pacific Coast: California and Washington	21,587
Total:	
1964	21,587
1963	41,473
U.S. total:	
1964	201,834
1963	226,736

[1] Excludes rerolling rails during 1964.

TABLE 15.—Consumption of iron and steel scrap by type of manufacturers by grades, in 1964

(Thousand short tons)

Grades of scrap	Steel ingots and castings	Steel castings	Iron foundries and miscellaneous users
Steel scrap, excludes rerolling rails:			
Carbon	58,435	2,958	4,511
Alloy, excludes stainless	2,716	148	156
Stainless	777	35	27
Cast iron, includes borings	5,343	386	9,133
Total:			
1964	67,271	3,527	13,827
1963	59,291	3,054	12,276

TABLE 16.—Consumption of iron and steel scrap, by grades, by districts and States, in 1964

(Short tons)

District and State	Carbon steel (excludes rerolling rails)	Alloy steel (excludes stainless)	Stainless steel	Cast iron (includes borings)
New England:				
Connecticut	86,967	7,992	27,351	54,875
Maine and New Hampshire	4,402	---	---	8,821
Massachusetts	35,206	---	1,369	163,538
Rhode Island	60,109	3,905	---	40,302
Vermont	3,821	---	---	18,221
Total:				
1964	190,505	11,897	28,720	285,757
1963	172,498	10,875	21,909	257,299
Middle Atlantic:				
New Jersey	361,999	11,102	5,202	390,037
New York	2,642,279	94,990	64,312	551,044
Pennsylvania	12,760,059	1,396,068	372,105	2,129,419
Total:				
1964	15,764,337	1,502,160	441,619	3,070,500
1963	13,352,751	1,282,042	395,299	2,662,228
East North Central:				
Illinois	6,877,148	200,338	51,809	1,572,305
Indiana	8,538,542	104,175	20,932	912,382
Michigan	5,455,476	44,631	104,495	2,789,297
Ohio	11,546,954	839,875	110,355	2,126,078
Wisconsin	534,580	4,539	3,330	484,255
Total:				
1964	32,952,700	1,193,558	290,921	7,884,317
1963	29,198,036	1,135,330	221,435	7,303,734
West North Central:				
Iowa	330,901	---	696	240,987
Kansas and Nebraska	106,081	---	10	40,520
Minnesota	345,448	5,863	503	133,105
Missouri	853,928	6,944	1,186	166,800
Total:				
1964	1,636,358	12,807	2,395	581,412
1963	1,456,580	11,612	1,965	551,603
South Atlantic:				
Delaware and Maryland	3,189,891	27,751	65,271	205,062
Florida and Georgia	445,921	---	---	35,479
North Carolina	10,649	---	---	80,403
South Carolina	8,048	7,245	(1)	36,501
Virginia and West Virginia	1,812,160	6,864	---	216,402
Total:				
1964	5,466,669	41,860	65,271	573,847
1963	4,709,217	29,918	60,051	580,604
East South Central:				
Alabama	2,182,423	51,454	W	795,952
Kentucky, Mississippi, Tennessee	1,552,890	79,340	W	452,802
Total:				
1964	3,735,313	130,794	W	1,248,754
1963	3,262,978	80,572	W	1,132,948
West South Central:				
Arkansas, Louisiana, Oklahoma	204,814	178	---	43,115
Texas	1,539,497	36,117	W	467,479
Total:				
1964	1,744,311	36,295	W	510,594
1963	1,482,205	30,762	W	430,016
Rocky Mountain:				
Arizona and Nevada	162,568	500	---	29,486
Colorado, Idaho, Montana, Utah	1,495,644	47,646	---	233,280
Total:				
1964	1,658,212	48,146	---	262,766
1963	1,469,045	40,037	---	284,452

See footnotes at end of table.

TABLE 16.—Consumption of iron and steel scrap, by grades, by districts and States, in 1964—Continued

(Short tons)

District and State	Carbon steel (excludes rerolling rails)	Alloy steel (excludes stainless)	Stainless steel	Cast iron (includes borings)
Pacific Coast:				
California and Hawaii	2, 172, 264	28, 287	1, 429	411, 354
Oregon and Washington	583, 804	14, 489	2, 434	32, 897
Total:				
1964	2, 756, 068	42, 776	3, 863	444, 251
1963	2, 489, 171	34, 039	6, 065	454, 022
U.S. total:				
1964	65, 904, 473	3, 020, 293	838, 700	14, 862, 198
1963	57, 592, 481	2, 655, 187	716, 156	13, 656, 906

W Withheld to avoid disclosing individual company confidential data; included in U.S. total.
[1] Data for South Carolina included in total for Delaware and Maryland.

TABLE 17.—Home scrap produced by source, by type of manufacturers in 1964

(Thousand short tons)

	Source of scrap			Total
	Recirculating [1]	Obsolete	Other, including slag	
Manufacturers of steel ingots and castings [2]	39, 609	3, 313	1, 852	44, 774
Manufacturers of steel castings	1, 490	5	1	1, 496
Iron foundries and miscellaneous users	5, 959	28	5	5, 992
Total:				
1964	47, 058	3, 346	1, 858	52, 262
1963	40, 566	2, 747	1, 342	44, 655

[1] Includes home, plant, or recycled iron and steel scrap.
[2] Includes molds, stools, machinery, and buildings; excludes rerolling rails.

TABLE 18.—Consumers receipts and total consumption of iron and steel scrap by grades, in 1964

(Thousand short tons)

Grades of scrap (excludes rerolling rails)	Receipts			Total consumption
	From dealers	From others	Total	
Carbon steel:				
Low phosphorus plate and punchings	2, 498	661	3, 159	3, 997
Cut structurals and plate	876	41	917	1, 001
Steel car wheels	127	35	162	167
No. 1 heavy melting	4, 672	2, 198	6, 870	29, 127
No. 1 and electric furnace bundles	4, 500	1, 550	6, 050	6, 858
No. 2 and all other bundles	4, 813	439	5, 252	6, 486
Turnings and borings	2, 102	167	2, 269	2, 508
Slag scrap (Fe content)	325	493	818	2, 942
All other carbon steel scrap	3, 006	887	3, 893	12, 819
Alloy steel, excludes stainless	389	197	586	3, 020
Stainless steel	265	46	311	839
Cast iron: Borings	794	393	1, 187	1, 543
All other cast iron scrap	4, 154	1, 036	5, 190	13, 319
Total: 1964	28, 521	8, 143	36, 664	84, 626
1963	26, 009	6, 239	32, 248	74, 621

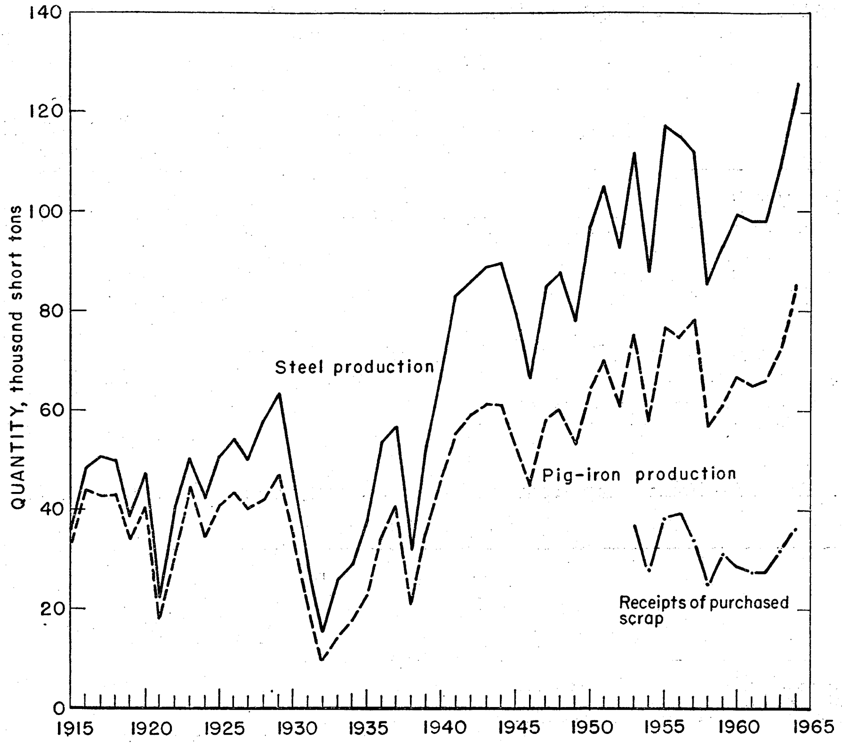

FIGURE 1.—Production of pig iron and steel and receipts of purchased scrap.

TABLE 19.—Iron and steel scrap production, receipts, consumption, consumer stocks, imports and exports

(Thousand short tons)

Year	Home scrap produced	Purchased scrap received from dealers and all others	Consumption	Stocks Dec. 31	Imports [1]	Exports [2]
1960	39,632	28,469	66,469	9,288	179	7,055
1961	38,475	27,553	64,327	8,824	268	9,714
1962	40,645	27,499	66,160	8,471	210	5,112
1963	44,655	32,248	74,621	r7,945	217	6,364
1964	52,262	36,664	84,626	7,413	282	7,886

r Revised.
[1] Includes tinplate scrap.
[2] Excludes circles, cables, strip, and scroll shear butts from tinplated scrap.

STOCKS

All districts except the Pacific Coast showed a drop in scrap stocks during 1964, with the West South Central and the West North Central showing decreases of 28 and 25 percent, respectively. The most scrap was held at the end of January with 7.8 million tons and the low point of supply was at the end of May, with 6.9 million tons. The average daily consumption rate during 1964 was 232,000 tons per day. Pig iron stocks were 12 percent less at the end of 1964.

TABLE 20.—Consumer stocks of iron and steel scrap and pig iron Dec. 31, in the United States, by districts and States

(Short tons)

District and State	1963		1964	
	Scrap [r]	Pig iron [r]	Scrap	Pig iron
New England:				
Connecticut	14,416	4,331	15,020	4,066
Maine and New Hampshire	722	326	773	204
Massachusetts	14,446	6,926	13,633	6,784
Rhode Island	13,763	6,741	13,251	4,870
Vermont	1,254	562	1,630	416
Total	44,601	18,886	44,307	16,340
Middle Atlantic:				
New Jersey	70,252	18,397	78,038	21,843
New York	536,594	349,625	683,801	334,793
Pennsylvania	1,917,963	559,799	1,436,650	487,562
Total	2,524,809	927,821	2,198,489	844,198
East North Central:				
Illinois	833,357	164,289	866,288	289,568
Indiana	742,300	55,525	886,358	99,380
Michigan	476,231	207,378	388,334	172,145
Ohio	1,060,827	632.908	962,397	388,984
Wisconsin	51,972	20,821	56,939	27.261
Total	3.164,687	1,080,921	3,160,316	977,338
West North Central:				
Iowa	44,905	7,136	47,944	5,185
Kansas and Nebraska	13,520	589	8,776	826
Minnesota	66,416	27,241	55,989	28,525
Missouri	202,756	15,675	131,517	11,081
Total	327,597	50,641	244,226	45,617
South Atlantic:				
Delaware and Maryland	312,326	60,361	224,738	45,573
Florida and Georgia	63,640	1,379	51,804	2,056
North Carolina	6,633	1,775	13,034	1,851
South Carolina	2,851	2,198	2,922	2,696
Virginia and West Virginia	120,443	89,084	158,360	43,904
Total	505,893	154,797	450,858	96,080
East South Central:				
Alabama	287,551	317,752	259,466	291,330
Kentucky, Mississippi, Tennessee	201,063	63,999	185,674	18,491
Total	488,614	381,751	445,140	309,821
West South Central:				
Arkansas, Louisiana, Oklahoma	28,652	1,428	16,859	1,405
Texas	190,464	30,873	139,909	37,875
Total	219,116	32,301	156,768	39,280
Rocky Mountain:				
Arizona, Nevada, Colorado, Idaho, Montana, Utah	228,099	91,877	220,505	82,322
Total	228,099	91,877	220,505	82,322
Pacific Coast:				
California and Hawaii	334,204	43,465	360 138	45,868
Oregon and Washington	107,666	23,526	132,266	4,542
Total	441,870	66,991	492,404	50,410
U.S. total	7,945,286	2,805,986	7,413,013	2,461,406

[r] Revised.

TABLE 21.—Consumer stocks of iron and steel scrap, by grades, by districts and States, Dec. 31, 1964

(Short tons)

District and State	Carbon steel (excludes rerolling rails)	Alloy steel (excludes stainless)	Stainless steel	Cast iron (includes borings)
New England:				
Connecticut	5,395	834	1,897	7,075
Maine and New Hampshire	124			649
Massachusetts	5,479			8,042
Rhode Island	9,586			3,596
Vermont	546			1,084
Total:				
1964	21,130	834	1,897	20,446
1963	22,867	803	1,376	19,555
Middle Atlantic:				
New Jersey	48,806	1,232	320	27,680
New York	489,945	10,293	25,354	158,209
Pennsylvania	950,427	172,714	38,383	275,126
Total:				
1964	1,489,178	184,239	64,057	461,015
1963	1,897,167	199,445	53,143	366,934
East North Central:				
Illinois	625,741	23,674	2,756	214,117
Indiana	570,081	17,327	1,554	297,396
Michigan	274,423	2,483	9,998	101,430
Ohio	715,783	51,986	11,455	183,173
Wisconsin	31,206	50	116	25,567
Total:				
1964	2,217,234	95,520	25,879	821,683
1963	2,334,581	149,571	53,216	627,319
West North Central:				
Iowa	38,224	------------	284	9,504
Kansas and Nebraska	7,774	------------		1,002
Minnesota	42,218	1,789		12,954
Missouri	86,793			43,684
Total:				
1964	175,009	1,789	284	67,144
1963	232,966	1,404	407	92,820
South Atlantic:				
Delaware and Maryland	194,519	3,132	[1] 8,171	19,107
Florida and Georgia	48,456	------------	------------	3,348
North Carolina	10,728	------------	------------	2,306
South Carolina	529	688	(1)	1,514
Virginia and West Virginia	145,674	1,464	------------	11,222
Total:				
1964	399,906	5,284	8,171	37,497
1963	431,068	7,550	10,629	56,646
East South Central:				
Alabama	203,200	24,920	W	55,969
Kentucky, Mississippi, Tennessee	135,637		W	23,239
Total:				
1964	338,837	24,920	W	79,208
1963	393,159	14,821	W	78,888
West South Central:				
Arkansas, Louisiana Oklahoma	10,946	------------	------------	5,913
Texas	111,809	9,243	W	18,749
Total:				
1964	122,755	9,243	W	24,662
1963	180,809	8,134	W	29,888
Rocky Mountain:				
Arizona and Nevada	17,571	306	------------	2,393
Colorado, Idaho, Montana, Utah	154,683	4,360	------------	41,192
Total:				
1964	172,254	4,666	------------	43,585
1963	179,723	9,390	------------	38,986

See footnotes at end of table.

TABLE 21.—Consumer stocks of iron and steel scrap, by grades, by districts and States, Dec. 31, 1964—Continued

(Short tons)

District and State	Carbon steel (excludes rerolling rails)	Alloy steel (excludes stainless)	Stainless steel	Cast iron (includes borings)
Pacific Coast:				
California and Hawaii	247,682	1,252	327	110,877
Oregon and Washington	123,203	1,619	330	7,114
Total:				
1964	370,885	2,871	657	117,991
1963	377,753	5,819	866	57,432
U.S. total:				
1964	5,307,188	329,366	103,228	1,673,231
1963	6,050,093	396,937	121,668	1,368,468

W Withheld to avoid disclosing individual company confidential data.
[1] Data for South Carolina included in total for Delaware and Maryland.

TABLE 22.—Consumer stocks, production, receipts, consumption, and shipments of iron and steel scrap, by grades, in 1964

(Thousand short tons)

	Stocks Jan. 1 r	Home scrap produced	Receipts from dealers and all others	Total consumption	Shipments	Stocks Dec. 31
Steel scrap, excludes rerolling rails:						
Carbon	6,050	39,386	29,390	65,905	3,615	5,307
Alloy, excludes stainless	398	2,554	585	3,020	187	330
Stainless	122	540	311	839	32	103
Cast iron, includes borings	1,375	9,782	6,378	14,862	999	1,673
Total	7,945	52,262	36,664	84,626	4,833	7,413

r Revised.

TABLE 23.—Stocks of iron and steel scrap and pig iron at major consuming industries plants, Dec. 31

(Thousand short tons)

Year	Manufacturers of steel ingots and castings	Manufacturers of steel casting	Iron foundries and miscellaneous users	Total
	Scrap stocks			
1962 r	7,179	427	865	8,471
1963 r	6,703	349	893	7,945
1964	6,148	372	893	7,413
	Pig iron stocks			
1962 r	2,591	27	449	3,067
1963 r	2,368	31	407	2,806
1964	2,029	27	405	2,461

r Revised.

PRICES[2]

The extreme price fluctuations characteristic of the scrap market were evident in 1964 as the price of No. 1 heavy melting varied from $26.50 in Philadelphia in January to $43.30 in Chicago in August. Even No. 2 bundles, with a composite average of $22.69, varied from $19.10 in Chicago in March to $27.30 in Pittsburgh in August. The average price of scrap advanced steadily throughout the year as a result of the record in steel ingot production. Composite prices tend to eliminate extremes, but even composite prices for the last 5 years show large fluctuations.

	1960	1961	1962	1963	1964
No. 1 heavy melting	$32.95	$36.28	$28.23	$27.11	$33.67
No. 2 bundles	22.15	24.72	20.45	19.85	22.69

The average price per ton of scrap exported from the United States rose to $34.53 during 1964 (see table 1).

TABLE 24.—Average monthly price and composite price for No. 1 heavy melting scrap in 1964

(Per long ton)

Month	Chicago	Pittsburgh	Philadelphia	Composite price [1]
January	$31.50	$28.50	$26.50	$28.83
February	30.00	28.50	27.50	28.66
March	30.10	28.90	28.50	29.17
April	31.75	31.25	29.37	30.79
May	32.50	33.50	29.50	31.83
June	34.90	34.50	29.50	32.97
July	37.50	35.50	30.00	34.33
August	43.30	36.70	33.50	37.84
September	39.50	36.50	33.50	38.50
October	38.75	37.50	33.50	36.58
November	40.10	39.10	33.90	37.70
December [e]	41.50	39.75	35.50	38.91
Average:				
1964 [e]	35.95	34.18	30.89	33.67
1963 [r]	29.50	26.58	25.27	27.11

[e] Estimate. [r] Revised.
[1] Composite price, Chicago, Pittsburgh, Philadelphia.

Source: Iron Age, January 1965.

TABLE 25.—Stocks, production, receipts, consumption and shipments of pig iron

(Thousand short tons)

Year	Stocks Jan. 1, 1964	Production	Receipts	Consumption	Shipments	Stocks Dec. 31, 1964
1963	3,067	71,741	7,524	72,689	[r] 6,837	[r] 2,806
1964	2,806	85,693	7,584	86,382	7,239	2,461

[r] Revised.

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[2] Iron Age. V. 195, No. 1, Jan. 7, 1965, p. 194.

FOREIGN TRADE

Canada continued to supply 96 percent of the scrap imported into the United States but this country exported 3 times as much scrap to Canada.

Exports to South America in 1964 were five times those in 1963. The European market recovered to the 1962 level as steel production continued high in the Common Market. The scrap market contributed nearly one-quarter of a billion dollars towards a favorable balance in world trade for the United States.

TABLE 26.—U.S. imports for consumption of iron and steel scrap, by countries

(Short tons)

Country	1963	1964
North America:		
Bahamas	90	29
Barbados	------	258
Canada	209,116	269,153
Dominican Republic	------	511
French West Indies	555	------
Mexico	805	301
Netherlands Antilles	3,660	------
Trinidad and Tobago	785	------
Total	215,011	270,252
South America:		
Brazil	------	1
British Guiana	535	------
Chile	------	1
Colombia	35	------
Total	570	2
Europe:		
France	8	598
Germany, West	694	5,553
Greece	------	5
Italy	------	807
Netherlands	84	131
Norway	45	------
Spain	------	3,856
Sweden	2	------
Switzerland	67	------
United Kingdom	546	320
Total	1,446	11,270
Asia:		
India	12	29
Japan	38	64
Total	50	93
Africa: South Africa, Republic of	103	------
Oceania: Australia	27	72
Grand total:		
Short tons	217,207	281,689
Value	$6,103,825	$8,252,742

Source: Bureau of the Census.

TABLE 27.—U.S. imports for consumption and exports of iron and steel scrap by classes

Class	1963		1964	
	Short tons	Value	Short tons	Value
Imports:				
Iron and steel scrap	195,383	$5,700,646	259,178	$7,780,828
Tinplate scrap	21,824	403,179	22,561	471,914
Total	217,207	6,103,825	281,739	8,252,742
Exports:				
Nos. 1 and 2 heavy-melting steel scrap	3,636,851	104,377,652	4,386,323	145,950,027
Nos. 1 and 2 baled steel scrap	1,621,047	36,578,611	2,161,445	55,351,612
Borings, shovelings, and turnings	196,603	4,175,651	261,984	5,547,079
Iron scrap	345,831	9,380,408	388,104	11,360,377
Rerolling material	146,446	6,900,424	132,214	6,647,497
Other steel scrap (terneplate and tinplated) [1]	416,839	13,198,423	556,399	18,266,055
Total	6,363,617	174,611,169	7,886,469	243,122,647

[1] Excludes circles, cobbles, strip, and scroll shear butts from tinplated scrap.

Source: Bureau of the Census.

TABLE 28.—U.S. exports of iron and steel scrap, by countries

(Short tons)

Destination	Iron and steel scrap including tinplate and terneplate scrap [1]		Rerolling material	
	1963	1964	1963	1964
North America:				
Canada	531,851	844,033	74	960
Mexico	468,955	794,790	101	6,708
Nicaragua	14,140	832		
Other	67	200		
Total	1,015,013	1,639,855	175	7,668
South America:				
Argentina	13,674	176,096		
Bolivia	58			
Brazil	1,044	252		16
Chile	4,361		30	
Colombia	30	10,693		
Peru	10,641	23,340		
Venezuela	10,807	164		
Total	40,615	210,545	30	16
Europe:				
France	6,475	110,527		
Germany, West	13,442	494,104		
Italy	951,034	662,019		
Netherlands	140	26,590		
Spain	34,090	190,350		
Sweden	15	184,478		
United Kingdom	366	903	103	1,435
Yugoslavia		53,923		
Other	11			
Total	1,005,573	1,722,894	103	1,435
Asia:				
Hong Kong	2,197	19	6,496	181
India	590	696		
Israel	3,556			
Japan	3,929,124	3,889,005	109,775	24,552
Korea, South	54,316	41,456	4,712	
Nansei and Nanpo Islands		3,908	6,297	2,672
Philippines	36	10,852		
Taiwan	113,591	144,252	18,858	95,690
Turkey	10,672	26,495		
Other	383	1,150		
Total	4,114,465	4,117,833	146,138	123,095
Africa:				
South Africa, Republic of	57	21,520		
United Arab Republic (Egypt)	41,335	41,486		
Other		6		
Total	41,392	63,012		
Oceania: Australia	113	116		
Grand total:				
Short tons	6,217,171	7,754,255	146,446	132,214
Value	$167,710,745	$236,475,150	$6,900,424	$6,647,497

[1] Excludes circles, cobbles, strip, and scroll shear butts from tinplated scrap.

Source: Bureau of the Census.

WORLD REVIEW

EUROPE

European Coal and Steel Community (ECSC).—The European Coal and Steel Community (ECSC) reimposed a total ban on exports of iron and steel scrap to third countries starting June 1, 1964. The export ban was considered necessary because of the high price of U.S. scrap and the ban on exports from the United Kingdom.

The consensus of delegates to the Bureau International de la Récuperation (BIR) at its Congress in Amsterdam was that international trade in scrap should not be subject to embargo. Although there was an upswing in 1964 steel production in the various ECSC countries ranging from 12 to 20 percent which absorbed all of the scrap available, most of the delegates agreed that free trade would be much better.[3]

France.—Although steel production increased in France in 1964, the scrap consumption rose only about 2 percent. This is felt to be a general decline in the use of scrap brought about by the adoption of the oxygen converter process.

United Kingdom.—In January the Restrictive Practices Court announced the decision that the agreement between the British Iron and Steel Federation and the National Federation of Scrap Iron, Steel and Metal Merchants was not contrary to the public interest. This decision resulted from the 34-day trial ending in December 1963.[4]

The United Kingdom issued a new Open General License, effective April 28, permitting the export to any destination of iron and steel scrap in the following forms: (1) Compressed baled material and (2) turnings and borings other than material wholly or partly coated or clad with copper, or alloys containing 50 percent or more by weight of copper.

The National Federation of Scrap Iron, Steel and Metal Merchants in cooperation with British Railways was considering the possibility of developing scrap concentration centers where full use could be made of modern processing techniques. These centers would reduce complaints about unsightliness and noise, since they could be located in heavily industrialized areas.

An oxy-propane cropping machine which can cut through a 22-inch-diameter steel roll at the rate of 6 inches per minute replaced the explosive, gelignite, for the breaking up of scrap steel mill rolls. The cropping machine can do the job faster than the explosive and for the same cost. With gelignite the work could be done only on weekends and the results often were segments that were too large. With the machine the cutting can take place at any time and the pieces can be cut to sizes suitable for feeding directly into the furnace.[5]

ASIA

India.—The ferrous scrap export policy announced in 1964 by the Iron and Steel Controller continued the restrictions on the export of No. 1 sheet cuttings, steel turnings and borings, and the heavy melting scrap. In addition, the policy has imposed quota restrictions on skull scrap and detinned scrap. India exported about 445,000 tons of scrap in 1964 as compared with 410,000 tons in 1963.

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[3] Metal Bulletin (London). No. 4901, June 2, 1964, p. 18.
[4] Metal Bulletin (London). No. 4868, Jan. 31, 1964, p. 11.
[5] European Chemical News (London). V. 6, No. 138, Sept. 4, 1964, p. 36.

TECHNOLOGY

Automation of the scrap processing industry is accelerating. The amount of equipment being installed to bring about this acceleration varies with the size, location, and kind of scrap processed.

Guillotine shears, presses, balers, and vibrating conveyors of all sizes are now available to processing yards. Shredders range in size from mills which take several whole car bodies per hour, producing a dense, clean scrap in one completely automatic operation, to smaller machines built to handle just the sheet metal parts of auto bodies. Handling of prompt industrial scrap is being mechanized. Also the handling of scrap in the charging aisle of the mill has been improved and automated because the use of oxygen has speeded up the steel refining process and charging time must be reduced.

The FOS (Fuel-Oxygen-Scrap) steelmaking process is being evaluated in England on a pilot plant scale. When used in conjunction with the Toroidal Oxy-Fuel burner, which was specifically designed to melt cold charges, the FOS process seems likely to be comparable in operating cost to electric-arc furnaces and have much lower initial capital costs.[6]

Oxygen-gas burners have been used in open-hearth furnaces to make steel with an all-steel scrap or "no-iron" charge.[7]

Various preheaters have been announced which would increase the amount of scrap feasible in a basic oxygen furnace from 25 to 40 percent.

Turnings and borings have been substituted for ore fines in sinter plants in order to strengthen the sinter and raise productivity. Tests have been made using as much as 9 percent scrap in the total charge.[8]

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[6] Journal of Metals. An Economic Evaluation of the FOS Process. V. 16, No. 6, June 1964, pp. 516–519.
——. The Toroidal Oxy-Fuel Burner. V. 16, No. 6, June 1964, pp. 520, 521.

[7] Journal of Metals. Open Hearth Steel From an All-Scrap Charge. V. 16, No. 11, November 1964, pp. 891–893.

[8] Iron Age. Scrap and Sinter. New Bedfellows. V. 193, No. 13, Mar. 26, 1964, pp. 97–99.

Iron Oxide Pigments

By Horace T. Reno [1]

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IRON OXIDE PIGMENTS became of increasing interest in 1964 for use as a raw material for producing the high-purity iron powder and ferrite used in the electronic industry.

TABLE 1.—Salient iron oxide pigments statistics in the United States

	1955–59 (average)	1960	1961	1962	1963	1964
Mine production................short tons..	53,600	70, 300	46, 000	57, 500	r 56, 700	58, 900
Crude pigments sold or used.....do....	51,900	71, 100	45, 900	60, 100	55, 900	59, 300
Value....................thousands..	$453	$635	$453	$500	$500	$443
Finished pigments sold......short tons..	110,000	106, 000	106, 500	113, 000	118, 800	119, 500
Value....................thousands..	$17,168	$17, 948	$18, 345	$19, 798	$21, 135	$22, 991
Imports for consumption....short tons..	13,300	14, 500	10, 500	13, 100	13, 700	16, 300
Value....................thousands..	$1,273	$1, 422	$1, 059	$1, 295	$1, 469	$1, 817
Exports....................short tons..	4,300	3, 900	3, 200	3, 800	4, 200	5, 100
Value....................thousands..	$989	$1, 113	$855	$1, 076	$1, 306	$1, 817

r Revised.

DOMESTIC PRODUCTION

Finished iron oxide pigments were sold by 13 companies with 17 plants in 8 States. Seven companies in six States mined, sold, or used crude iron oxide pigments. Detailed sales data reported in table 2 are not strictly comparable with those for previous years because producers in some instances classified pigments as natural rather than manufactured. This classification often is a matter of choice as to whether beneficiation of crude ore is simple concentration or a manufacturing process.

CONSUMPTION AND USES

The Bureau of Mines does not obtain data on the use of either natural or manufactured iron oxide pigments. It has been assumed that essentially all the oxides were used by the paint industry. In 1964, however, the large number of inquiries as to possible sources of pure oxides from companies in the electronic industries indicated that the high purity of iron oxide pigments was of increasing interest in the manufacture of electronic devices.

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[1] Commodity specialist, Division of Minerals.

TABLE 2.—Finished iron oxide pigments sold by processors in the United States, by kinds

Pigment	1963		1964	
	Short tons	Value	Short tons	Value
Natural:				
Brown:				
Iron oxide (metallic) [1]	8,045	$984,800	14,164	$2,431,300
Umbers:				
Burnt	3,237	554,800	2,922	582,900
Raw	672	111,200	737	143,900
Red:				
Iron oxide	14,769	764,400	27,351	1,338,000
Sienna, burnt	1,114	257,000	1,140	337,000
Pyrite cinder	1,613	86,400	3,104	179,200
Yellow:				
Ocher [2]	3,419	173,700	3,156	177,800
Sienna, raw	701	155,500	622	152,200
Total natural	33,570	3,087,800	53,196	5,342,300
Manufactured:				
Black: Magnetic	2,278	683,900	2,713	820,400
Brown: Iron oxide	2,509	949,000	3,165	1,487,000
Red:				
Pure red iron oxides:				
Calcined copperas	16,936	4,802,400	18,866	5,240,300
Other chemical processes	10,553	3,007,600	8,988	2,553,200
Other manufactured red iron oxides	21,518	2,426,900	3,346	769,300
Venetian red	1,645	220,100	1,313	196,700
Yellow: Iron oxide	18,082	4,502,700	19,360	5,101,800
Total manufactured	73,521	16,592,600	57,751	16,168,700
Unspecified including mixtures of natural and manufactured red iron oxides	11,756	1,454,600	8,592	1,480,000
Grand total	118,847	21,135,000	119,539	22,991,000

[1] Includes some black magnetite and vandyke brown.
[2] Includes some yellow iron oxide.

PRICES

Fluctuations in the quoted prices shown in table 3 were the result of different methods used by various trade journals in obtaining data. Some changes in prices were also caused by differences in quantity, quality, locality, or individual suppliers' views.

TABLE 3.—Prices quoted on finished iron oxide pigments, per pound, in bags, unless otherwise specified, in 1964

Pigment	High	Low	Pigment	High	Low
Black:			Red:		
Pure	$0.1550	$0.1500	Domestic (pure)	$0.1450	$0.1450
Synthetic	.1500	.1475	Persian Gulf	.0950	.0950
Brown:			Sienna, burnt	.2200	.0725
Pure	.1650	.1600	Yellow:		
Metallic	.0650	.0600	Ocher, natural, French	.0700	.0700
Umber, American, burnt	.1100	.0850	Ocher, natural, Peruvian	.0250	.0250
Umber, American, raw	.1100	.0850	Ocher, hydrated, pure	.1350	.1275
Vandyke	[1] .1100	.1100	Sienna, raw	.2200	.0750
			Other shades	.1275	.1225

[1] Barrels.

Source: Oil, Paint and Drug Reporter and Chemical & Engineering News.

FOREIGN TRADE

All the processed ochers and more than half the natural ochers imported for consumption in the United States, as in 1963, originated in the Republic of South Africa. Crude and washed siennas originated principally in Italy and Cyprus, and the vandyke brown originated in West Germany. Cyprus supplied essentially all the crude, washed, and natural umbers.

West Germany supplied 62 percent of the synthetic iron oxide pigment imports, Canada supplied 20 percent, United Kingdom 14 percent, and France, Belgium-Luxembourg, Netherlands, and Sweden supplied the remaining 4 percent.

Exports of iron oxide pigments were valued at an average of 17.8 cents per pound in 1964, compared with 15.5 cents in 1963, and 14 cents in 1962.

TABLE 4.—U.S. imports for consumption of selected iron oxide pigments

Pigments	1963		1964	
	Short tons	Value	Short tons	Value
Natural:				
Ocher, crude and refined	144	$8, 397	191	$17, 614
Siennas, crude and refined	610	61, 825	726	97, 478
Umber, crude and refined	2, 641	94, 543	3, 412	117, 934
Vandyke brown	217	17, 516	259	21, 133
Other [1]	2, 877	136, 996	2, 902	136, 159
Total	6, 489	319, 277	7, 490	390, 318
Manufactured (synthetic)	7, 215	1, 149, 507	8, 829	1, 426, 211
Grand total	13, 704	1, 468, 784	16, 319	1, 816, 529

[1] Classified by the Bureau of the Census as "Natural iron-oxide and iron-hydroxide pigments, n.s.p.f."

Source: Bureau of the Census.

TABLE 5.—U.S. imports for consumption of iron-oxide and iron-hydroxide pigments, n.s.p.f.,[1] by countries

Country	Natural				Synthetic			
	1963		1964		1963		1964	
	Short tons	Value	Short tons	Value	Short tons	Value	Short tons	Value
North America: Canada	5	$786	30	$2, 813	1, 429	$300, 196	1, 784	$364, 957
Europe:								
Belgium-Luxembourg	------	------	------	------	------	------	41	6, 475
France	165	12, 600	------	------	138	20, 035	196	26, 068
Germany, West	66	9, 065	35	6, 125	4, 747	685, 038	5, 507	832, 267
Netherlands	------	------	------	------	------	------	57	8, 553
Portugal	112	2, 807	------	------	------	------	------	------
Spain	2, 438	105, 646	2, 758	115, 575	------	------	------	------
Sweden	------	------	------	------	10	8, 530	2	1, 861
United Kingdom	40	4, 812	79	11, 646	891	135. 708	1, 242	186, 030
Total	2, 821	134, 930	2, 872	133, 346	5, 786	849, 311	7, 045	1, 061, 254
Asia: India	51	1, 280	------	------	------	------	------	------
Grand total	2, 877	136, 996	2, 902	136, 159	7, 215	1, 149, 507	8, 829	1, 426, 211

[1] Not specifically provided for.

Source: Bureau of the Census.

TABLE 6.—U.S. exports of iron oxide pigments, by countries

Destination	1963		1964	
	Short tons	Value	Short tons	Value
North America:				
Canada	2,047	$480,864	1,957	$453,055
Costa Rica	8	2,589	7	2,839
Guatemala	39	9,837	26	7,238
Mexico	37	16,765	50	26,257
Netherlands Antilles	13	4,606	13	2,742
Panama	19	6,979	10	4,907
Other	13	4,809	64	22,196
Total	2,176	526,449	2,127	519,234
South America:				
Argentina	6	1,990	67	30,415
Brazil	15	4,829	15	8,487
Chile	11	2,805	19	7,579
Colombia	109	39,027	128	56,462
Ecuador	8	2,300	7	2,730
Peru	18	5,403	33	7,015
Venezuela	112	35,709	178	53,761
Other	2	650	6	3,585
Total	281	92,713	453	170,034
Europe:				
Belgium-Luxembourg	42	16,694	36	11,486
France	84	28,151	143	49,419
Germany, West	109	41,689	266	141,457
Italy	137	81,500	77	77,571
Netherlands	56	2,562	68	7,552
Portugal	19	6,209	7	2,228
Sweden	30	7,615	30	14,098
Switzerland	51	16,129	34	15,618
United Kingdom	154	86,156	680	350,057
Other	18	6,262	(1)	386
Total	700	292,967	1,341	669,872
Asia:				
Hong Kong	6	2,433	5	2,486
Indonesia	36	10,240	---	---
Japan	345	96,089	501	140,268
Lebanon	7	2,265	12	17,907
Pakistan	20	7,673	5	1,352
Philippines	168	53,086	130	43,304
Other	27	14,688	23	9,867
Total	609	186,474	676	215,184
Africa:				
South Africa, Republic of	53	14,297	77	16,381
Other	8	4,484	4	1,602
Total	61	18,781	81	17,983
Oceania	362	188,786	419	224,195
Grand total	4,189	1,306,170	5,097	1,816,502

[1] Less than ½ unit.

Source: Bureau of the Census.

WORLD REVIEW

Canada.—Canada produced 914 tons of iron oxide pigments valued at Can$79,015 in 1964, compared with 978 tons (revised) valued at Can$74,505 (revised) in 1963. All that was produced in 1964 was mined in Quebec Province, but Ferrox Iron Limited, of Prescott, Ontario, was formed to produce high-purity iron oxide for pigments by flotation and high-density separation. The operation will be unique in Canada inasmuch as other iron oxide pigments are produced using chemical processes.

Cyprus.— Cyprus produced 6,746 tons of umber valued at $220,842 and 460 tons of yellow ocher valued at $23,632. Exports of powdered and unpowdered raw umber totaled 992 tons, and exports of powdered and unpowdered burnt umber totaled 5,752 tons. All the ocher was exported without treatment.

India.—India produced 28,056 tons of ocher valued at $152,250 in 1964, compared with 20,991 tons (revised) valued at $102,000 (revised) in 1963.

South Africa, Republic of.—The Republic of South Africa produced 4,037 tons of ocher and 1,447 tons of oxide in 1964. Exports of ocher, principally to the United Kingdom, totaled 3,121 tons valued at $96,412. Exports of oxide totaled 55 tons valued at $2,780.[2] The remainders of the ocher and the oxide produced were sold to local customers in the Republic.

TECHNOLOGY

Apparently there was little activity in iron oxide pigment technology in 1964. However, German chemists described a modified method for determining the critical pigment volume concentration based on measurement of ion permeability,[3] and radioactive tracer studies of the yellow iron oxide pigment were reported by Russian investigators.[4] The Russians also reported their investigation of the relations between the shade of the yellow pigments and their composition, structure, and fineness.[5]

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[2] Department of Mines, Republic of South Africa. Quarterly Information Circular, October–December 1964, 108 pp.

[3] Kresse, Peter. (Iron Oxides Paint Critical Pigment Volume Concentration and Its Relation to Flocculation and Dispersion Phenomena.) F.A.T.I.P.E.C. (Fed. Assoc. Techniciens Ind. Peintures, Vernis, Emaux, Encres, Imprimerie Europe Continental), 7th Congress, 1964, pp. 205–209 (in German).

[4] Smelov, E. A., and V. M. Bochkarev. (Radioactive Tracer Study of the Formation of the Yellow Iron Oxide Pigment.) Lakokrasochnye Materialy i ikh Primenenie, v. 4, 1964, pp. 70–72.

[5] Smelov, E. A., A. I. Sheinkman, and Yu. Ya. Bobyrenko. (Relations Between the Shade of Yellow Iron Oxide Pigments and Their Composition, Structure, and Fineness.) Lakokrasochnye Materialy i ikh Primenenie, v. 3, 1964, pp. 20–23.

Kyanite and Related Minerals

By James D. Cooper[1]

⁂

KYANITE and synthetic mullite production in the United States reached record rates in 1964, and estimated domestic consumption from all sources exceeded 100,000 tons. Kyanite concentrate production was up 14 percent, and synthetic mullite production was up 22 percent over the respective figures for 1963.

Kyanite, sillimanite, andalusite, dumortierite, topaz, and synthetic mullite are included in this chapter because all are aluminum silicates with similar properties, which can be used to produce mullite refractories.

DOMESTIC PRODUCTION

For the fourth successive year domestic production of minus 35-mesh kyanite concentrate reached a record high. Output of crude kyanite ore was 7 percent above the 1963 total, and production of concentrate was up 14 percent, indicating a marked improvement in the concentrate-to-ore ratio. Quantitative data on kyanite production are withheld to prevent disclosure of individual company data. In 1964 there were three producers—Aluminum Silicates, Inc., with a mine near Lincolnton, Ga.; Commercialores, Inc., with mines near Clover, S.C.; and Kyanite Mining Corp., with mines near Farmville and Dillwyn, Va.

Synthetic mullite was produced in the United States by electric furnace fusion and by sintering, using a variety of aluminous and siliceous materials such as bauxite, Bayer-process alumina, clays, and silica sand. Output increased 22 percent over the previous record of 29,588 tons reported in 1963. There were seven producers:

The Babcock & Wilcox Co., Refractories Division, New York, N.Y. (plant at Augusta, Ga.).

The Carborundum Co., Niagara Falls, N.Y. (plant at Niagara Falls, N.Y.).

Harbison-Walker Refractories Co., Pittsburgh, Pa. (plant at Eufaula, Ala.).

Norton Co., Worcester, Mass. (plant at Huntsville, Ala.).

H. K. Porter Co., Inc., Refractories Division, Pittsburgh, Pa. (plant at Shelton, Conn.).

Remmey Division of A. P. Green Fire Brick Co., Philadelphia, Pa. (plant at same address).

The Chas. Taylor Sons Co., subsidiary of National Lead Co., Cincinnati, Ohio (plant at South Shore, Ky.).

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[1] Commodity specialist, Division of Minerals.

TABLE 1.—Synthetic mullite production in the United States

Year	Short tons	Value (thousands)	Year	Short tons	Value (thousands)
1955–59 (average)	[a] 19,000	[a] $2,000	1962	19,021	$2,090
1960	21,497	2,212	1963	29,588	3,529
1961	14,798	1,720	1964	36,108	4,450

[a] Estimate.

CONSUMPTION AND USES

Kyanite and related minerals were used principally in refractories, with smaller but significant quantities going into ceramic products ranging from electrical insulators to floor and wall tile.

Mullite refractories are resistant to spalling, slagging, and chemical reactions, and have low thermal expansion and reheat shrinkage. They were used extensively to line furnaces for melting high-copper brasses and bronzes, copper-nickel alloys, and certain steels. In glass furnaces mullite refractories were used in critical areas such as the metal line, port arches, crowns, and pouring spouts. In many cases arch and hearth supports, door linings, electrode openings, and other critical furnace areas were made of the highest purity mullite products available.

In ceramic products kyanite was beneficial in a number of ways. Workability was often improved, and this in turn increased production rates and reduced losses due to processing defects; the growth of interlocking mullite crystals in the products during the firing process increased their strength; and expansion of the kyanite on conversion to mullite was used to compensate for firing shrinkage of other materials in the ceramic mixes.

PRICES

Prices for domestic kyanite increased slightly in 1964 but the delivered price for imported kyanite remained unchanged. Prices quoted in E&MJ Metal and Mineral Markets on November 30, 1964, were as follows:

Kyanite, short ton, f.o.b. Virginia and South Carolina:

35 mesh, carlots, bulk	$47
35 mesh, carlots, bags	50
200 mesh, carlots, bags	58
Imported kyanite, 60 percent grade, bags, c.i.f. Atlantic ports	76–81

FOREIGN TRADE

Imports of kyanite group minerals decreased for the fourth straight year, and with exception of 1958, the total was the lowest since import data first became available in 1937. India supplied nearly 98 percent of the 1964 imports, with the balance coming from mines in South-West Africa but shipped from the Republic of South Africa.

Exports of domestic kyanite, which have increased rapidly in recent years, were up 20 percent from those of 1963, for a new record high. Canada, United Kingdom, Federal Republic of Germany, and Mexico were the major recipients, accounting for 68 percent of the total quantity exported. More than 20 other countries received quantities ranging from 1 to 553 tons.

TABLE 2.—U.S. imports for consumption and exports of kyanite and related minerals

Country	1955-59 (average)		1960		1961		1962		1963		1964	
	Short tons	Value	Short tons	Value	Short tons	Value	Short tons	Value	Short tons	Value	Short tons	Value
Imports:												
North America: Canada	------	------	------	------	------	------	108	$9,980	59	$5,287	------	------
Europe:												
Netherlands	9	$842	------	------	255	$19,143	------	------	------	------	------	------
United Kingdom	2	170	------	------	------	------	------	------	------	------	------	------
Asia: India	3,709	182,991	4,684	$213,764	3,809	173,307	3,845	174,948	2,500	110,532	2,329	$101,307
Africa:												
South Africa, Republic of	1,861	62,205	1,368	51,600	1,351	51,739	1,328	49,483	65	3,299	57	2,300
Oceania: Australia	45	4,927	------	------	------	------	------	------	------	------	------	------
Total	5,626	251,135	6,052	265,364	5,415	244,189	5,281	234,411	2,624	119,118	2,386	103,607
Exports:												
North America:												
Canada	1,192	59,372	1,630	108,718	647	100,237	611	100,480	765	133,360	1,680	109,548
Dominican Republic	2	132	------	------	------	------	2	208	------	------	10	696
Mexico	601	27,986	788	39,983	677	33,748	587	33,073	698	42,952	704	36,435
Trinidad and Tobago	------	------	------	------	------	------	------	------	6	1,156	4	980
South America:												
Argentina	6	396	------	------	76	4,314	53	3,028	44	2,500	84	4,790
Brazil	------	------	------	------	------	------	------	------	2	586	18	1,607
Chile	------	------	5	330	------	------	------	------	------	------	------	------
Colombia	------	------	------	------	------	------	15	757	------	------	------	------
Peru	4	740	------	------	------	------	------	------	------	------	2	204
Uruguay	------	------	------	------	------	------	------	------	3	667	------	------
Venezuela	------	------	65	4,759	37	4,642	81	3,782	228	16,409	323	17,396
Europe:												
Austria	------	------	17	941	11	1,285	------	------	------	------	------	------
Belgium-Luxembourg	------	------	2	533	------	------	30	1,377	------	------	45	2,470
Finland	------	------	------	------	------	------	30	1,746	40	2,304	------	------
France	27	2,128	143	8,403	45	2,821	99	7,012	204	38,669	98	7,398
Germany, West	86	4,740	288	17,893	395	30,252	719	45,464	939	53,524	953	54,453
Italy	106	6,465	63	3,660	135	9,379	424	28,426	459	42,535	370	32,079
Netherlands	26	1,420	------	------	46	4,362	------	------	18	1,007	------	------
Portugal	2	132	------	------	------	------	3	384	------	------	------	------
Spain	------	------	------	------	------	------	------	------	53	5,491	15	3,826
Sweden	------	------	------	------	------	------	20	1,020	------	------	22	1,142
United Kingdom	52	5,543	86	11,442	878	50,536	530	30,754	625	40,782	788	47,183
Yugoslavia	------	------	------	------	------	------	22	5,452	------	------	------	------

TABLE 2.—U.S. imports for consumption and exports of kyanite and related minerals—Continued

Country	1955-59 (average)		1960		1960		1962		1963		1964	
	Short tons	Value	Short tons	Value	Short tons	Value	Short tons	Value	Short tons	Value	Short tons	Value
Exports—Continued												
Asia:												
Hong Kong							4	1,000			90	5,000
Indonesia	18	1,333			89	5,200	57	3,248				
Israel											9	550
Japan	50	4,566	163	12,452	880	64,668	242	15,792	862	53,203	553	38,829
Jordan			5	836								
Philippines											72	4,718
Taiwan											1	204
Thailand											3	864
Vietnam					30	2,559						
Africa:												
South Africa, Republic of					34	2,590					2	666
Sudan									1	252		
Oceania:												
Australia					20	1,040	39	3,737	103	6,673	226	21,507
New Zealand											8	612
Total	2,172	114,953	3,255	209,950	4,000	317,633	3,568	286,740	5,050	442,070	6,080	393,157

Source: Bureau of the Census.

WORLD REVIEW

Australia.—Output of kyanite group minerals was 3,937 tons in 1963, almost evenly divided between the Broken Hill District in New South Wales and the Mt. Crawford area in South Australia. Production in 1962 was 2,953 tons.

British Guiana.—A 50,000 tons per year synthetic mullite plant was under construction at McKenzie. The plant, costing $1.3 million, was expected to employ 30 men.[2]

India.—Kyanite production in 1964 was 37,579 tons compared with 34,904 tons in 1963. Sillimanite production rose to 13,627 tons from 12,439 tons in 1963.

Korea, South.—Output of kyanite group minerals showed a threefold increase in 1963, with a total of 2,208 tons. Kyanite production was 1,450 tons, and andalusite production was 758 tons.

Southern Rhodesia.—A total of 258 tons of kyanite was produced in 1964, all of which was reported during the first 8 months of the year. Output in 1963 was 60 tons.

South Africa, Republic of.—Production of kyanite group minerals in 1964 consisted of 60,241 tons of sillimanite and 15,402 tons of andalusite. Most of the sillimanite, and about half the andalusite, was exported, principally to Japan, United Kingdom, and Federal Republic of Germany.[3]

An immense deposit of andalusite near Chuniespoort, northern Transvaal, was explored by cross trenching over a strike length of 15 miles. The deposit, which lies mostly within a Bantu area (Bantustan), has a stratigraphic thickness of about 300 feet and contains 20 to 30 percent andalusite.[4]

South-West Africa.—Mining of kyanite and sillimanite was resumed after a 1-year lapse, and 612 tons was produced in 1964. Approximately 57 tons was exported to the United States.

TECHNOLOGY

Heat contents and entropies were accurately determined by laboratory measurements for kyanite, sillimanite, and andalusite at temperatures from 298.15° K to the approximate temperatures where rapid conversion to mullite and cristobalite begins at atmospheric pressure. Heats of formation of the three minerals from corundum and cristobalite were determined to be less negative than -6 Kcal/mole based on the experimental data, compared with previously accepted values of -40 to -45 Kcal/mole.[5] Independent computation of the heat of formation for kyanite based on analysis of high pressure-high temperature data was in excellent agreement with this determination.[6]

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[2] Commercial Review. (British Guiana). Government Grants Demba Concession for New Industry. May to June, 1964, p. 72.

[3] Republic of South Africa, Department of Mines, Quarterly Inf. Cir. Minerals, July to September, 1964, pp. 26, 67–68.

[4] Bureau of Mines. Mineral Trade Notes. V. 59, No. 6, December 1964, p. 7.

[5] Pankratz, L. B., and K. K. Kelley. High-Temperature Heat Contents and Entropies of Andalusite, Kyanite, and Sillimanite. BuMines Rept. of Inv. 6370, 1964, 7 pp.

[6] Haskell, R. W., and R. C. DeVries. Estimate of Free Energy of Formation of Kyanite. J. Am. Ceram. Soc., v. 47, No. 4, April 1964, pp. 202–203; correction in J. Am. Ceram. Soc., v. 47, No. 5, May 1964, p. 254.

Synthetic mullite and other high alumina refractories were tested for reheat and hot load properties in a furnace equipped to test two bricks simultaneously. This assured identical heating times, temperatures, and heating rates. Rapid expansion of the mullite brick, which was caused by mullite growth at grain boundries did not occur until after the brick became thermoplastic.[7]

Uncalcined kyanite was one of the principal ingredients in a patented castable refractory for alkali-resistant blast furnace linings.[8] The durability of conventional steel furnace linings was improved by a patented coating material containing 55 percent sillimanite and smaller amounts of magnesia, alumina, and fluorspar.[9]

Results of a study were published giving information on the minor elements present and the optical properties of a number of kyanites from various geological settings, mostly in Minas Gerais, Brazil. One comparison sample was from a magnesite deposit in Bahia. There was no correlation between optical and chemical data or between optical data and mode of occurrence.[10]

Revised data were submitted for high pressure-high temperature experiments on andalusite, sillimanite, kyanite, and 1:1 alumina-silica gel. Pressure-temperature data for kyanite and the gel were nearly identical, but were considerably different from the sillimanite and andalusite data.[11]

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[7] Churovich, M. D., K. Weisenstein, and W. L. Babianic. Simultaneous Hot Load and Reheat Testing of High Alumina Refractories. Am. Ceram. Soc. Bull., v. 43, No. 11, November 1964, pp. 842–845.

[8] Harbison-Walker Refractories Co. British Pat. 946,905, Jan. 15, 1964.

[9] Dortmund-Horder Huttenunion A. G. British Pat. 962,205, July 1, 1964.

[10] Herz, Norman, and C. V. Dutra. Geochemistry of Some Kyanites From Brazil. Am. Mineral., v. 49, Nos. 9 and 10, September-October 1964, pp. 1290–1305.

[11] DeVries, R. C. The System Al_2SiO_5 at High Temperatures and Pressures. J. Am. Ceram, Soc., v. 47, No. 5, May 1964, pp. 230–237.

Lead

By Donald E. Moulds[1]

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PRODUCTION and consumption of lead as reported by the domestic lead industry continued to rise in 1964, while imports for consumption of ores and metal declined. At yearend stocks of refined and antimonial lead at both primary plants and consumer and secondary plants were reduced. Mine production of recoverable lead increased 13 percent to 286,000 tons, a total last exceeded in 1957, and production of primary refined and antimonial lead rose 13 percent to 458,000 tons. Recovery of lead from secondary materials by both primary and secondary plants increased 10 percent to a record 541,600 tons. Consumption of lead as reported increased 3 percent to slightly over 1.2 million tons with gasoline antiknock additives contributing the major portion of the increase, while storage battery requirements declined from the high level of 1963. Government sale of 41,000 tons of lead from the stockpile in August and 9,000 tons in November completed the 50,000 tons authorized under Public Law 88–374.

The price of common lead in New York advanced from the 12.50 cents per pound quoted at the end of 1963 to 13 cents on January 2, 1964; three subsequent increases of 1 cent per pound brought the price to 16 cents per pound on December 11, 1964. London Metal Exchange price ranged from a low of 9.6 cents per pound in January to a high of 19.2 cents, U.S. equivalent, in December. The average price for the year was 13.6 cents per pound, New York, and 12.6 cents on the London Metal Exchange.

LEGISLATION AND GOVERNMENT PROGRAMS

The small mines stabilization program under Public Law 87–374, enacted in October 1961, applied to eligible production of lead during the year. Qualifications for participation in the program were amended by enactment of Public Law 88–75 and a subsequent amendment of the program rules and regulations. As of December 31, 1964, those mines certified under the amended program totaled 61. Payment of $144,902 was made on sales of 6,144 tons of eligible lead during the year to 48 small mining concerns. The New York price of lead exceeded the 14.5 cents per pound, below which payment is authorized, in October.

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[1] Commodity specialist, Division of Minerals.

The Government did not acquire lead for the stockpile during the year. Disposal of 50,000 tons of lead to meet indicated commercial shortage was authorized under Public Law 88-373 enacted in July. During August approximately 41,000 tons was sold by General Services Administration and the remaining 9,000 tons was sold in November. Sale was restricted to domestic use and allocated to domestic producers of primary and secondary refined lead, qualified importers of refined lead, and consumers qualifying as small business concerns. Shipment of lead by the Government as a result of the sale reduced the Government stockpile inventory to 1,338,130 tons of lead at yearend, all of which has been determined by the Office of Emergency Planning to be surplus to stockpile requirements for conventional war.

Government participation in exploration projects for lead and zinc, under the program of the Office of Minerals Exploration, was withdrawn at the end of June 1962. Of the four projects for lead and zinc approved prior to this action and active in 1964, one was certified as a discovery and the remaining projects terminated during the year.

Import quotas on lead ores and metal, established October 1, 1958, continued in effect. The quotas subdivided into quarterly quotas for specified countries were essentially filled for lead metal in all of the quarters, while receipts of lead in ores and bullion were less than the quota limitation in each quarter and represented only 90 percent of that allowable for the year. The President, on March 2, 1964, requested the U.S. Tariff Commission to advise him in determinating whether or not to relax or terminate the import quotas pursuant to the provisions of the Trade Expansion Act of 1962. This investigation was still in progress at yearend.

Legislation was reintroduced in Congress in February to establish flexible quotas on lead and zinc ores and metal and also on specified manufactured lead and zinc products. This legislation was still pending in Congress at yearend.

The International Lead and Zinc Study Group held its eighth session in Madrid, Spain, from October 26 to October 30. Representatives of 24 of the participating countries attended the sessions. The Group reviewed statistics on free world production and consumption of lead and zinc, as well as trade with countries with centrally planned economies. The Group concluded that free world consumption in 1963-64 had exceeded production and resulted in a drastic reduction of producer stocks and increased prices for lead and zinc, and while a significant increase in production was indicated in 1965-67, the imbalance in supply-demand would be likely to persist in 1965. Discussions of the Group stressed the importance of trade liberalization in lead and zinc and the study of intergovernmental agreements designed to achieve greater stability in lead and zinc. Measures to continue study in these two areas and also in medium-range aspects of supply and demand were approved.

TABLE 1.—Salient lead statistics

	1955-59 (average)	1960	1961	1962	1963	1964
United States:						
Production:						
Domestic ores, recoverable lead content short tons	310,406	246,669	261,921	236,956	253,369	286,010
Value thousands	$85,920	$57,722	$53,956	$43,602	$54,727	$74,936
Primary lead (refined):						
From domestic ores and base bullion short tons	302,469	228,899	288,078	245,645	239,660	294,254
From foreign ores and base bullion short tons	170,748	153,537	161,487	130,418	155,072	155,175
Antimonial lead (primary lead content) short tons	15,392	2,385	24,966	27,383	[r] 9,256	8,607
Secondary lead (lead content) short tons	470,242	469,903	452,792	444,202	493,471	541,582
Imports, general:						
Lead in ores and matte do	182,568	145,692	147,186	138,631	147,742	123,257
Lead in base bullion do	131	293	422	4,599	5,437	4,838
Lead in pigs, bars, and old short tons	309,666	213,671	261,794	259,522	235,902	212,898
Exports of refined pig lead do	2,697	1,967	2,133	2,108	1,088	10,175
Stocks December 31 (lead content):						
At primary smelters and refineries short tons	147,154	250,142	262,102	196,661	120,836	84,398
At consumer plants do	124,032	97,268	99,140	93,496	119,930	113,444
Consumption of metal, primary and secondary short tons	1,127,602	1,021,172	1,027,216	1,109,635	1,163,358	1,202,138
Price: New York, common lead, average, cents per pound	14.03	11.95	10.87	9.63	11.14	13.62
World:						
Production:						
Mine	2,555,000	2,620,000	2,630,000	2,765,000	2,805,000	2,735,000
Smelter	2,415,000	2,550,000	2,660,000	2,650,000	2,750,000	2,830,000
Price: London, common lead, average, cents per pound	11.35	9.04	8.03	7.06	7.93	12.59

[r] Revised.

DOMESTIC PRODUCTION

MINE PRODUCTION

Domestic mine production was essentially uninterrupted during the year. The output of 286,000 tons of recoverable lead represented a 13-percent increase in relation to the 1963 output, which had been affected by the strike closure of the southeast Missouri mines throughout the first quarter of 1963. The production rate was relatively stable, ranging from 22,800 tons in the short month of February to a top of 25,000 tons in December. Missouri was again the leading lead-producing State with an output of 120,100 tons, last exceeded in 1957, followed by Idaho, 71,300 tons; Utah, 40,200 tons; and Colorado, 20,600 tons. These four States produced 252,300 tons or 88 percent of the U.S. total; the remaining 12 percent represented the output of 15 States. Of the 19 States reporting lead production, the 1964 output increased in 10 of the States while decreasing in the other 9 in comparison to that of 1963. The 25 leading lead-producing mines contributed 264,300 tons or 92 percent of the total domestic output. Production from the 4 largest mines amounted to 57 percent of the total and from the 10 leading mines was 79 percent.

The continuing demand for lead, especially for concentrates, to augment diminishing receipts and stocks of foreign material for smelting provided an incentive for exploration and development of lead deposits as well as for reopening of mines and expansion of production.

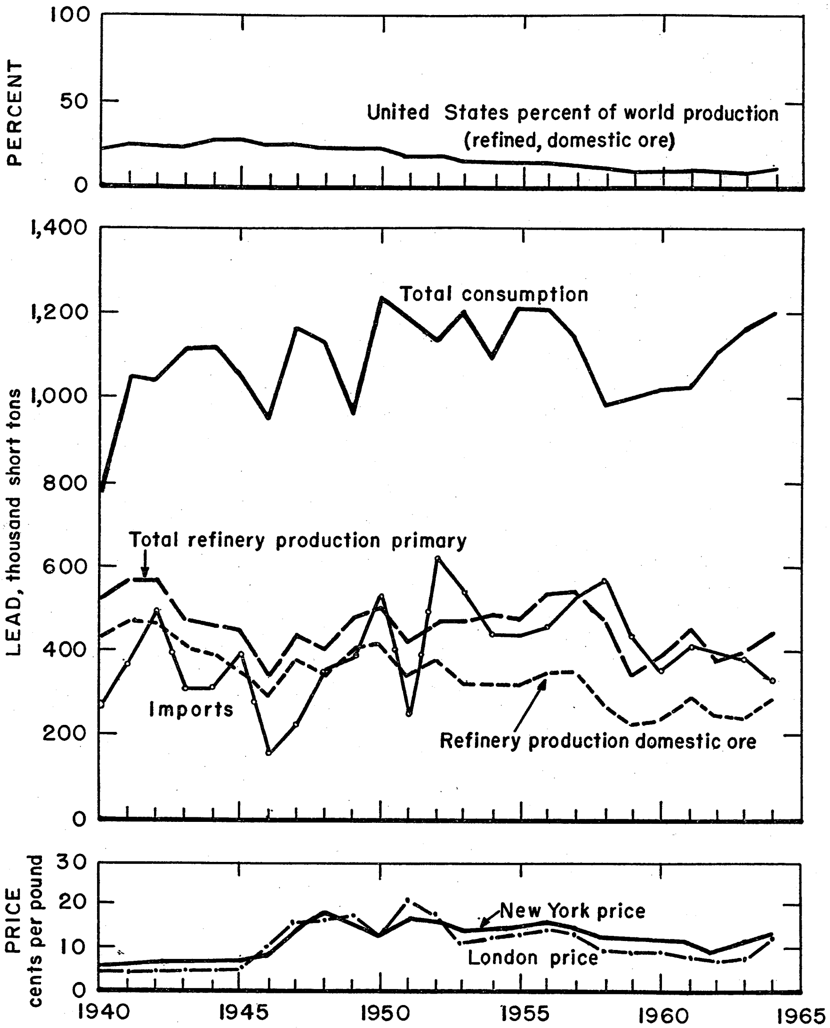

FIGURE 1.—Trends in the lead industry in the United States. Consumption includes primary refined, antimonial, and secondary lead and lead in pigments made directly from ore. Imports are factored to include 95 percent of lead content or ores, mattes, and concentrates and 100 percent of pigs, bars, base bullion, and scrap.

TABLE 2.—**Mine production of recoverable lead in the United States, by States**

(Short tons)

State	1955–59 (average)	1960	1961	1962	1963	1964
Arizona	11,229	8,495	5,937	6,966	5,815	6,147
Arkansas	8	-----	-----	-----	-----	-----
California	4,277	440	103	455	823	1,546
Colorado	16,737	18,080	17,755	17,411	19,918	20,563
Idaho	63,224	42,907	71,476	84,058	75,759	71,312
Illinois	3,105	3,000	3,430	3,610	2,901	2,180
Kansas	3,834	781	1,449	970	1,027	1,185
Kentucky	315	558	656	743	831	858
Missouri	118,765	111,948	98,785	60,982	79,844	120,148
Montana	13,015	4,879	2,643	6,121	5,000	4,538
Nevada	4,232	987	1,791	771	1,126	809
New Mexico	3,315	1,996	2,332	1,134	1,014	1,626
New York	1,074	775	879	1,063	1,009	732
North Carolina	4	424	318	219	62	-----
Oklahoma	7,590	936	980	2,710	3,192	2,781
Utah	44,292	39,398	40,894	38,199	45,028	40,249
Virginia	2,976	2,152	3,733	4,059	3,500	3,857
Washington	10,812	7,725	8,053	6,033	5,374	5,731
Wisconsin	1,595	1,165	680	1,394	1,116	1,742
Other States	7	23	27	58	30	6
Total	310,406	246,669	261,921	236,956	253,369	286,010

Developments of major significance to the lead-producing industry continued in the southeast Missouri lead belt. St. Joseph Lead Co. created a new division to operate its new Fletcher mine and mill in Reynolds County. This project, along with expanded production from the Viburnum mine, was expected to provide an additional 100,000 tons of lead annually, and the Herculaneum smelter capacity was being expanded accordingly.

Montana Phosphate Products Co., a subsidiary of the Consolidated Mining & Smelting Co. of Canada, Ltd. (COMINCO), and Dresser Industries Inc., announced development of mining and concentrating facilities at the Magmont property near Bixby, Mo., with a capacity of 50,000 tons of lead annually, and scheduled for completion in late 1967 or early 1968.

American Metal Climax, Inc., and Homestake Mining Co. announced plans for joint development of a mine-mill project at properties near Buck, Mo., with a capacity of 50,000 tons of lead annually. Shaft sinking, mine development, and mill construction were expected to be completed by late 1967. The two companies also announced plans for a smelter-refinery project with a capacity of 100,000 tons of lead annually to smelt the concentrates from their mine and those produced by the COMINCO-Dresser operations.

TABLE 3.—Ores yielding lead and zinc in the United States in 1964

(Short tons)

State	Lead ore			Zinc ore			Lead-zinc ore			Copper-lead, copper-zinc, and copper-lead-zinc ores			All other sources [1]			Total		
	Gross weight	Lead	Zinc	Gross weight	Lead	Zinc	Gross weight	Lead	Zinc	Gross weight	Lead	Zinc	Gross weight	Lead	Zinc	Gross weight	Lead	Zinc
Arizona	3, 157	479	30	15, 714	23	874	314, 187	5, 527	15, 804	114, 314	90	7, 307	27, 924, 313	28	675	28, 371, 685	6, 147	24, 690
California	1, 999	1, 078	2	----------	--------	--------	3, 600	467	140	----------	--------	--------	580	1	1	6, 179	1, 546	143
Colorado	1, 320	104	11	294, 264	3, 245	27, 562	224, 375	6, 714	10, 246	477, 678	10, 276	15, 738	53, 175	224	125	1, 050, 812	20, 563	53, 682
Idaho	211, 036	21, 220	1, 897	(2)	(2)	(2)	[2] 923, 111	[2] 47, 091	[2] 52, 944	----------	--------	--------	443, 626	3, 001	4, 457	1, 577, 773	71, 312	59, 298
Illinois	----------	--------	--------	177, 894	28	4, 618	----------	--------	--------	----------	--------	--------	359, 247	2, 152	9, 182	537, 141	2, 180	13, 800
Kansas	----------	--------	--------	93, 190	441	2, 714	112, 063	744	1, 951	----------	--------	--------	----------	--------	--------	205, 253	1, 185	4, 665
Kentucky	----------	--------	--------	8, 068	--------	901	----------	--------	--------	----------	--------	--------	134, 029	858	1, 162	142, 097	858	2, 063
Missouri	4, 965, 814	120, 148	1, 501	----------	--------	--------	----------	--------	--------	----------	--------	--------	----------	--------	--------	4, 965, 814	120, 148	1, 501
Montana	6, 359	473	104	1, 080, 743	2, 682	20, 251	201	16	15	----------	--------	--------	166, 101	1, 367	8, 689	1, 253, 404	4, 538	29, 059
Nevada	1, 990	242	71	1, 491	18	442	----------	--------	--------	----------	--------	--------	21, 555	549	69	25, 036	809	582
New Mexico	119	16	1	384, 318	758	28, 462	16, 926	814	1, 334	----------	--------	--------	7, 412, 754	38	36	7, 814, 117	1, 626	29, 833
Oklahoma	----------	--------	--------	243, 021	1, 038	7, 720	243, 524	1, 743	4, 439	----------	--------	--------	----------	--------	--------	486, 545	2, 781	12, 159
Tennessee	----------	--------	--------	3, 655, 328	--------	106, 043	----------	--------	--------	1, 447, 120	--------	9, 900	----------	--------	--------	5, 102, 448	--------	115, 943
Utah	6, 588	921	228	9	--------	1	514, 038	38, 630	28, 590	1, 207	201	78	44, 403	497	2, 531	566, 245	40, 249	31, 428
Washington	282	19	--------	(2)	(2)	(2)	[2] 995, 968	[2] 5, 712	[2] 24, 296	----------	--------	--------	----------	--------	--------	996, 250	5, 731	24, 296
Wisconsin	----------	--------	--------	849, 943	1, 742	26, 278	----------	--------	--------	----------	--------	--------	----------	--------	--------	849, 943	1, 742	26, 278
New Jersey	----------	--------	--------	902, 140	--------	32, 926	1, 242, 953	--------	--------	----------	--------	--------	----------	--------	--------	2, 145, 093	--------	32, 926
New York						11, 392		732	49, 362								732	60, 754
Pennsylvania						30, 754		--------	--------								--------	30, 754
Virginia						--------		3, 857	21, 004								3, 857	21, 004
Other States	----------	--------	--------	----------	--------	--------	----------	--------	--------	----------	--------	--------	1, 704	6	W	1, 704	6	W
Total	5, 198, 664	144, 700	3, 845	7, 706, 123	9, 975	300, 938	4, 590, 946	112, 047	210, 125	2, 040, 319	10, 567	33, 023	36, 561, 487	8, 721	26, 927	56, 097, 539	286, 010	574, 858

W Withheld to avoid disclosing individual company confidential data.

[1] Lead and zinc recovered from other ores (copper, gold, silver, etc.) and from mill slags, tailings, and dumps.

[2] Combined with lead-zinc ore to avoid disclosing individual company confidential data.

TABLE 4.—Mine production of recoverable lead in the United States, by months

(Short tons)

Month	1963	1964	Month	1963	1964
January	15,476	24,907	August	24,470	23,620
February	13,180	22,799	September	22,511	22,937
March	14,772	24,454	October	25,241	23,775
April	20,786	24,054	November	22,999	23,388
May	24,083	23,547	December	23,930	25,047
June	22,322	24,037			
July	23,599	23,445	Total	253,369	286,010

TABLE 5.—Twenty-five leading lead-producing mines in the United States in 1964, in order of output

Rank	Mine	District or region	State	Operator	Source of lead
1	Federal	Southeastern Missouri.	Missouri	St. Joseph Lead Co.	Lead ore.
2	Viburnum	do	do	do	Do.
3	Bunker Hill	Coeur d'Alene	Idaho	The Bunker Hill Co.	Lead-zinc ore.
4	United States and Lark.	West Mountain (Bingham).	Utah	United States Smelting, Refining and Mining Co.	Lead-zinc, lead ore.
5	Lucky Friday	Coeur d'Alene	Idaho	Hecla Mining Co.	Lead ore.
6	Indian Creek	Southeastern Missouri.	Missouri	St. Joseph Lead Co.	Do.
7	Star-Morning unit.	Coeur d'Alene	Idaho	The Bunker Hill Co. and Hecla Mining Co.	Lead-zinc ore.
8	Idarado	Upper San Miguel.	Colorado	Idarado Mining Co.	Copper-lead-zinc ore.
9	Page	Coeur d'Alene	Idaho	American Smelting and Refining Co.	Lead-zinc ore.
10	United Park City	Uintah and Blue Ledge.	Utah	United Park City Mines Co.	Do.
11	Iron King	Big Bug	Arizona	Shattuck Denn Mining Corp.	Do.
12	Pend Oreille	Metaline	Washington	Pend Oreille Mines and Metals Co.	Do.
13	Mayflower Unit	Blue Ledge	Utah	Hecla Mining Co.	Do.
14	Austinville and Ivanhoe Mines.	Austinville	Virginia	The New Jersey Zinc Co.	Zinc-lead ore.
15	Sunnyside	Eureka	Colorado	Standard Metals Corp.	Lead-zinc ore.
16	Eagle	Red Cliff (Battle Mountain).	do	The New Jersey Zinc Co.	Zinc-copper ore.
17	Butte Hill Zinc Mines.	Summit Valley	Montana	The Anaconda Company.	Zinc ore.
18	Ophir Unit	Ophir	Utah	United States Smelting, Refining and Mining Co.	Lead-zinc ore.
19	Keystone	Elk Mountain	Colorado	McFarland and Hullinger.	Copper-lead, zinc ore.
20	Emperius	Creede	do	Emperius Mining Co.	Lead-zinc ore.
21	Fairview-Blue Diggings.	Upper Mississippi Valley.	Illinois	Aluminum Company of America.	Fluorspar-lead-zinc ore.
22	Jubilee	Resting Springs	California	Monte Cristo Mining Corp.	Lead ore.
23	Shullsburg	Upper Mississippi Valley.	Wisconsin	The Eagle-Picher Co.	Zinc ore.
24	Van Stone	Northport	Washington	American Smelting and Refining Co.	Do.
25	Dyers Hill	Western Kentucky.	Kentucky	Calvert City Chemical Co.	Calcium-fluorspar ore.

National Lead Co. and The Bunker Hill Co. signed an agreement for development of National Lead's Higdon property near Fredericktown, Mo. Exploration and development was in progress, but construction schedules and production tonnages were not announced. Ozark Mining Co., a subsidiary of Kennecott Copper Corp., was actively exploring its lead ore property in the Blair Creek, Mo., area. Several other companies continued exploration of leased areas in the new lead belt which occupies an area some 30 miles long by 10 miles wide.

Production of lead in Idaho declined from 75,800 tons in 1963 to 71,300 tons in 1964. The Bunker Hill Co. lead smelter was closed for 2 weeks in August for annual overhaul and again closed for 2 weeks in mid-October due to fire damage to the Cottrell plant and baghouse. Construction of a new sinter handling and storage system was initiated in September. The company also began handling custom milling of ore from small mine operators in the area. The incentive of improved prices for lead and silver resulted in major development programs, and reactivation of lead-silver mines in Idaho by many small operators as well as the larger producing companies. Day Mines, Inc., reactivated the Dayrock mill north of Wallace to treat ore from the reopened Monitor mine. Federal Resources Corp.'s new 300-ton-per-day mill at Bellevue started operations in April and will process ores from the company's mines as well as from custom shippers in the area. At yearend, approximately 1,200 feet remains to be driven to complete the 17,000-foot crosscut to connect the Bunker Hill and Crescent mines at an elevation 400 feet below sea level.

Utah mine output decreased from 45,000 tons in 1963 to 40,200 tons in 1964. The following mines were significant producers in 1964: United States and Lark (United States Smelting, Refining, and Mining Co. (USSR & M Co.)), United Park City (United Park City Mines Co.), Mayflower (Hecla Mining Co.), and Ophir (USSR & M Co.). New Park Mining Co. conducted exploration work on the 2,400-foot level of the Mammoth mine about 50 miles south of Salt Lake City.

Production of lead in Colorado was essentially the same as that of 1963. The revival of small mining operations continued, assisted in part by the reopening of the Bachelor mill north of the Ouray Badger Flats mill west of Colorado Springs. Nine properties operated by the following companies produced 98 percent of the State total: Idarado Mining Co., New Jersey Zinc Co., Standard Metals Corp., Camp Bird Colorado, Inc., Emperius Mining Co., McFarland and Hullinger, Humphreys Engineering Co., Wellington Mines Assoc., and Rico Argentine Mining Co.

Washington output increased to 5,700 tons, compared with 5,400 tons in 1963. The Pend Oreille mine, operated by Pend Oreille Mines and Metals Co., and the Van Stone mine, operated by American Smelting and Refining Co., were the principal producers. The Tri-Nite Mining Co. was preparing to reopen the Schumaker mine in Stevens County and install a concentrating plant. An open-pit mining operation by the Triton Mining Co. was underway at the old Castell mine.

Arizona output increased to 6,100 tons, with the Iron King mine of Shattuck Denn Mining Corp. the principal producer. The Arivaca Mining Corp. completed remodeling and enlarging its flotation mill and produced a copper-lead concentrate from ore of the Arizona mine near Ruby. E. W. McFarland operated the Hardshell mine in Santa Cruz County and was proceeding with the unwatering of the French and January mines which were last operated by American Smelting and Refining Co. in 1949.

Montana production decreased to 4,500 tons, principally due to a decline in production by The Anaconda Company. The old Tarbox mine near Saltese was being unwatered by Mineral King Mining Co. after being flooded since 1918. Exploration was in progress at the Cumberland mine near Lennep and at the Eddy Creek in Sanders County. Spokane National Mines, Inc., operated the New Departure mine near Dillon.

Reopening of the Hanover mine and the Oswaldo mine in late 1963, along with the Dearney mine production, increased New Mexico output to 1,600 tons from the 1,000 tons produced in 1963. Other reactivated mines include the Lynchburg mine in Socorro County and the Princess mine in Grant County.

California output, 1,500 tons, was almost double that of 1963. The Santa Rosa, Defense, Jubilee, and Bunker Hill mines in Inyo County were the principal producers.

Production from the Kansas-Oklahoma area of the Tri-State district, processed principally at the Central Mill operated by The Eagle-Picher Co., decreased to 4,000 tons for the year. The Illinois-Wisconsin area output also declined to about 3,900 tons of lead.

Nevada output declined to 800 tons from the 1,100 tons of 1963. The Silver King Mines, Inc., operated its mine at Ward Mountain, White Pine County, and 300-ton-per-day flotation plant near East Ely to produce both lead and zinc concentrates. The unwatering of the Fad shaft at Eureka was completed and development was underway by the Ruby Hill Mining Co.

Lead production, as a byproduct of predominantly zinc mines in New York, North Carolina, and Virginia and fluorspar mines in Kentucky, was approximately the same as that of 1963. The expanded production of Virginia did, however, offset the decline registered in the other States.

SMELTER AND REFINERY PRODUCTION

The domestic production of commercial lead as refined (soft lead) and as antimonial (hard lead) was derived from three principal sources: domestic mine production, imports of lead in ores and base bullion, and scrap materials of domestic origin. Ten primary plants operated by the following companies—American Smelting and Refining Co., The Bunker Hill Co., St. Joseph Lead Co., The Eagle-Picher Co., International Smelting & Refining Co., and United States Smelting Lead Refinery, Inc.—process ore and concentrates, base bullion, and small amounts of scrap. Secondary smelters essentially process only lead-base and tin-base scrap and recover the contained lead predominantly in the form of antimonial lead along with specification lead-base alloys and refined lead. The 25 major companies operating secondary plants and reporting to the Bureau of Mines were listed in the Minerals Yearbook, 1963. Secondary plants in 1964 produced a record 397,800 tons of refined lead and lead in antimonial lead and 121,900 tons of lead in other alloys.

Refined Lead, Primary and Secondary.—Refined lead produced in the United States from all sources—primary and secondary, plus remelt—totaled 598,600 tons, a 13-percent increase in relation to the 529,300 tons produced in 1963. Primary plants produced 449,400 tons from primary materials, of which 65 percent was supplied by domestic mines. An additional 8,500 tons of refined lead was produced by primary plants from scrap, in comparison with 3,700 tons in 1963 and the 2,900-ton average for the period 1955–62. Secondary plants produced a record 140,700 tons of refined lead from scrap, approximately 23 percent of the total. Remelt lead from all secondary materials amounted to 28,200 tons.

Antimonial Lead, Primary and Secondary.—The lead content of antimonial lead produced in the United States totaled 279,100 tons compared with the revised total of 254,100 tons in 1963. Secondary plant output was 257,100 tons, a record amount and 92 percent of the total. Primary plant output was 22,000 tons, of which 20 percent represented lead in domestic ore; 19 percent, foreign ore; and 61 percent, lead from scrap materials.

Raw Material Source.—Primary lead materials smelted and refined in primary plants provided 449,400 tons of refined lead and 8,600 tons of lead in antimonial lead. Domestic ores contributed 65 percent of the total, compared with 60 percent in 1963. Foreign lead ores and bullion consumed by primary smelters provided 159,300 tons, compared with 159,800 tons in 1963.

Secondary lead recovered from scrap amounted to 541,600 tons, the largest yearly recovery ever recorded by the Bureau of Mines. Of this, 149,200 tons was recovered as refined and remelt soft lead, 270,500 tons in antimonial lead, and 121,900 tons in the form of other alloys including copper-base and tin-base. Scrap consumed to obtain the lead amounted to 705,200 tons, gross weight, and an average recover-

TABLE 6.—Refined lead produced at primary refineries in the United States, by source material

(Short tons)

	1955–59 (average)	1960	1961	1962	1963	1964
Refined lead:						
From primary sources:						
Domestic ores and base bullion	302,469	228,899	288,078	245,645	239,660	294,254
Foreign ores and base bullion	170,748	153,537	161,487	130,418	155,072	155,175
Total	473,217	382,436	449,565	376,063	394,732	449,429
From secondary sources	2,989	4,776	1,569	1,842	3,741	8,505
Grand total	476,206	387,212	451,134	377,905	398,473	457,934
Average sales price per pound	$0.136	$0.117	$0.103	$0.093	$0.108	$0.131
Calculated value of primary refined lead (thousands)[1]	$128,715	$89,490	$92,610	$69,948	$85,262	$117,750

[1] Excludes value of refined lead produced from scrap at primary refineries.

able lead content of slightly less than 74 percent. Old scrap represented 87 percent of the total and storage battery scrap contributed 74 percent of the old scrap. Secondary lead recovered was valued at $142 million in comparison with $107 million in 1963.

TABLE 7.—Antimonial lead produced at primary lead refineries in the United States

Year	Production (short tons)	Antimony content		Lead content by difference (short tons)			
		Short tons	Percent	From domestic ore	From foreign ore	From scrap	Total
1955-59 (average)	57,278	2,939	5.1	7,394	7,998	38,947	54,339
1960	30,230	1,575	5.2	1,216	1,169	26,270	28,655
1961	35,080	1,894	5.4	12,988	11,978	8,220	33,186
1962	33,325	2,249	6.7	14,838	12,545	3,693	31,076
1963	[r] 18,818	1,890	[r] 10.0	[r] 4,553	[r] 4,703	7,672	[r] 16,928
1964	24,023	1,995	8.3	4,522	4,085	13,421	22,028

[r] Revised.

TABLE 8.—Stocks and consumption of new and old lead scrap in the United States in 1964

(Short tons, gross weight)

Class of consumers and type of scrap	Stocks Jan. 1 [r]	Receipts	Consumption			Stocks Dec. 31
			New scrap	Old scrap	Total	
Smelters and refiners:						
Soft lead	2,968	59,957		59,143	59,143	3,782
Hard lead	1,132	14,416		14,504	14,504	1,044
Cable lead	1,339	30,857		30,415	30,415	1,781
Battery-lead plates	35,256	458,570		455,532	455,532	38,294
Mixed common babbitt	383	2,922		3,038	3,038	267
Solder and tinny lead	402	11,079		11,142	11,142	339
Type metals	1,587	25,301		25,762	25,762	1,126
Drosses and residues	22,484	93,143	91,341		91,341	24,286
Total	65,551	696,245	91,341	599,536	690,877	70,919
Foundries and other manufacturers:						
Soft lead	130	56		159	159	27
Hard lead	267	73		99	99	241
Cable lead	21	48		57	57	12
Battery-lead plates	13					13
Mixed common babbitt	114	13,939		13,956	13,956	97
Solder and tinny lead		14		14	14	
Type metals						
Drosses and residues	201	2	1		1	202
Total	746	14,132	1	14,285	14,286	592
All consumers:						
Soft lead	3,098	60,013		59,302	59,302	3,809
Hard lead	1,399	14,489		14,603	14,603	1,285
Cable lead	1,360	30,905		30,472	30,472	1,793
Battery-lead plates	35,269	458,570		455,532	455,532	38,307
Mixed common babbitt	497	16,861		16,994	16,994	364
Solder and tinny lead	402	11,093		11,156	11,156	339
Type metals	1,587	25,301		25,762	25,762	1,126
Drosses and residues	22,685	93,145	91,342		91,342	24,488
Grand total	66,297	710,377	91,342	613,821	705,163	71,511

[r] Revised.

TABLE 9.—Secondary metal recovered[1] from lead and tin scrap in the United States in 1964, by type of products

(Short tons, gross weight)

	Lead	Tin	Antimony	Other	Total
Refined pig lead	121,028				121,028
Remelt lead	28,179				28,179
Total	149,207				149,207
Refined pig tin		3,355			3,355
Remelt tin		379			379
Total		3,734			3,734
Lead and tin alloys:					
Antimonial lead	270,522	367	16,199	234	287,322
Common babbitt	19,556	926	1,767	79	22,328
Genuine babbitt	67	283	30	12	392
Solder	30,178	6,188	488	25	36,879
Type metals	29,150	1,710	3,589	12	34,461
Cable lead	19,746	6	226		19,978
Miscellaneous alloys	1,578	586	40	39	2,243
Total	370,797	10,066	22,339	401	403,603
Tin content of chemical products		1,085			1,085
Grand total	520,004	14,885	22,339	401	557,629

[1] Most of the figures herein represent actual reported recovery of metal from scrap.

TABLE 10.—Secondary lead recovered in the United States

(Short tons)

	1955–59 (average)	1960	1961	1962	1963	1964
As metal:						
At primary plants	2,989	4,776	1,569	1,842	3,741	8,505
At other plants	122,955	143,443	139,100	116,626	130,788	140,702
Total	125,944	148,219	140,669	118,468	134,529	149,207
In antimonial lead:						
At primary plants	38,947	26,270	8,220	3,693	7,672	13,421
At other plants	186,600	179,217	197,349	225,699	237,125	257,101
Total	225,547	205,487	205,569	229,392	244,797	270,522
In other alloys	118,751	116,197	106,554	96,342	114,145	121,853
Grand total:						
Quantity	470,242	469,903	452,792	444,202	493,471	541,582
Value (thousands)	$129,298	$109,957	$93,275	$82,622	$106,590	$141,894

TABLE 11.—Lead recovered from scrap processed in the United States, by kind of scrap and form of recovery

(Short tons)

Kind of scrap	1963	1964
New scrap:		
Lead-base	59,577	64,876
Copper-base	6,094	6,490
Tin-base	611	555
Total	66,282	71,921
Old scrap:		
Battery-lead plates	272,412	304,523
All other lead-base	135,844	144,900
Copper-base	18,928	20,233
Tin-base	5	5
Total	427,189	469,661
Grand total	493,471	541,582

Form of recovery	1963	1964
As soft lead:		
At primary plants	3,741	8,505
At other plants	130,788	140,702
Total	134,529	149,207
In antimonial lead [1]	244,797	270,522
In other lead alloys	92,203	99,168
In copper-base alloys	21,878	22,618
In tin-base alloys	64	67
Total	358,942	392,375
Grand total	493,471	541,582

[1] Includes 7,672 tons of lead recovered in antimonial lead from secondary sources at primary plants in 1963 and 13,421 tons in 1964.

CONSUMPTION AND USES

Consumption of lead in the United States increased for the third successive year and the gain in 1964 was about 3.3 percent. Consumption in January was the largest monthly total and July, the smallest. The monthly average for the year slightly exceeded 100,000 tons. Soft lead consumed amounted to 773,800 tons in comparison with 740,200 tons in 1963 and represents the largest part of the increase. The lead in antimonial lead consumed amounted to 313,900 tons, slightly below the 314,400 tons in 1963. Lead in alloys consumed, lead in copper-base scrap, and lead that went directly from scrap to other fabricated products increased in comparison to 1963, while lead used in zinc oxide and other miscellaneous pigments decreased.

The use pattern reflected increased requirements for soft lead and essentially unchanged requirements for hard or antimonial lead in comparison with 1963. Storage battery plates, the major use of hard lead, decreased slightly and other end products such as type metal and cable covering also declined, while ammunition registered a gain. Gasoline additives requiring soft lead registered the largest increase, about 16 percent, a record amount for this product. Other end products of soft lead, such as pigments, sheet lead, and solder, also registered gains.

Storage battery requirements totaled 429,300 tons, approximately 10,000 tons less than in 1963. The Association of Battery Manufacturers, Inc., reported shipments of 29.3 million units of replacement batteries and total battery shipments of 38.8 million units, including exports, compared with shipments of 41.1 million units in 1963.

Industrial consumption of lead was widespread throughout the United States. Thirteen States accounted for 84 percent and four States—New Jersey, Illinois, Indiana, and California—used 45 percent.

New applications of lead in the ceramics, construction, and ballast areas, developed by research sponsored by producers and industrial consumers, while not individually of major significance, have collectively added to the lead consumption tonnage. Noise and vibration control applications have assumed greater importance in construction through availability of thin sheets, 0.5 to 3 pounds per square foot, which can be continuously cast and reinforced if desired. A new compound composed of lead pellets in an elastic matrix of neoprene rubber has found application. Solder glass composed of 65 to 80 percent lead oxide is of importance in sealing glass to metal. The ceramic industry is using lead compounds in glazes and porcelain enamels; a porcelain enamel for aluminum using lead oxide results in a high-quality product for architectural applications. Lead monoxide-silica compound forms a high-temperature dry lubricant. Nearly 375 tons of lead shot provides the test load for the Air Force Titan III missile system, and other applications from submarines to jewelry incorporate the high dimensional weight of lead advantageously.

TABLE 12.—Lead consumption in the United States, by products

(Short tons)

Product	1963	1964
Metal products:		
Ammunition	49,894	56,493
Bearing metals	21,713	22,754
Brass and bronze	21,943	23,328
Cable covering	57,707	56,225
Calking lead	76,308	73,628
Casting metals	7,856	6,961
Collapsible tubes	14,832	14,904
Foil	3,952	3,976
Pipes, traps, and bends	20,100	20,480
Sheet lead	26,495	29,605
Solder	67,945	71,186
Storage batteries:		
Battery grids, posts, etc	222,286	221,594
Battery oxides	216,795	207,754
Terne metal	1,983	1,609
Type metal	26,069	25,374
Total	835,878	835,871
Pigments:		
White lead	8,846	8,802
Red lead and litharge	70,649	74,802
Pigments—Continued		
Pigment colors	11,767	11,921
Other [1]	7,813	8,111
Total	99,075	103,636
Chemicals:		
Gasoline antiknock additives	192,811	223,466
Miscellaneous chemicals	632	451
Total	193,443	223,917
Miscellaneous uses:		
Annealing	4,847	5,699
Galvanizing	1,631	1,592
Lead plating	220	179
Weights and ballast	12,207	12,760
Total	18,905	20,230
Other, unclassified uses	16,057	18,484
Grand total [2]	1,163,358	1,202,138

[1] Includes lead content of leaded zinc oxide and other pigments.
[2] Includes lead which went directly from scrap to fabricated products.

TABLE 13.—Lead consumption in the United States, by months

(Short tons)

Month	1963	1964
January	100,789	107,603
February	96,023	94,425
March	92,606	92,844
April	95,340	98,981
May	98,264	98,786
June	94,024	102,448
July	85,648	91,438
August	93,833	99,676
September	94,587	101,765
October	111,149	105,571
November	101,723	101,985
December	99,372	106,616
Total [1]	1,163,358	1,202,138

[1] Includes lead content of leaded zinc oxide and other pigments and lead which went directly from scrap to fabricated products.

TABLE 14.—Lead consumption in the United States in 1964, by class of products and types of material

(Short tons)

Product	Soft	Lead in antimonial lead	Lead in alloys	Lead in copper-base scrap	Total
Metal products	208,440	88,061	49,594	17,857	363,952
Storage batteries	215,394	214,504	----	----	429,898
Pigments	99,713	233	----	----	99,946
Chemicals	223,915	2	----	----	223,917
Miscellaneous	10,517	8,858	10	----	19,385
Unclassified	15,787	2,257	643	----	18,687
Total	773,766	313,915	50,247	17,857	[1] 1,155,785

[1] Excludes 42,663 tons of lead which went directly from scrap to fabricated products and 3,690 tons of lead contained in leaded zinc oxide and other nonspecified pigments.

TABLE 15.—Lead consumption in 1964, by States [1]

(Short tons)

State	Refined soft lead	Lead in antimonial lead	Lead in alloys	Lead in copper-base scrap	Total
California	74,760	25,406	7,471	1,343	108,980
Colorado	1,651	2,205	277	---	4,133
Connecticut	13,663	11,903	61	1,153	26,780
District of Columbia	123	---	---	---	123
Florida	6,341	4,069	---	---	10,410
Georgia	33,743	10,818	2,086	110	46,757
Illinois	86,274	43,703	9,591	2,038	141,606
Indiana	68,417	42,251	2,361	959	113,988
Kansas	8,213	9,097	1	185	17,496
Kentucky	3,134	4,262	3	---	7,399
Maryland	5,294	15,300	510	---	21,104
Massachusetts	6,145	3,692	457	220	10,514
Michigan	17,642	19,077	1,833	694	39,246
Missouri	21,963	4,291	88	1,646	27,988
Nebraska	5,048	903	11	701	6,663
New Jersey	133,401	19,849	9,988	797	164,035
New York	35,250	3,874	8,231	1,075	48,430
Ohio	12,607	5,905	2,726	1,305	22,543
Pennsylvania	50,206	30,275	804	2,663	83,948
Rhode Island	1,370	429	22	---	1,821
Tennessee	191	7,326	69	160	7,746
Virginia	2,717	1,117	714	958	5,506
Washington	8,204	880	410	---	9,494
West Virginia	16,912	6,341	---	---	23,253
Wisconsin	1,973	3,564	65	189	5,791
Alabama and Mississippi	679	1,328	---	732	2,739
Arkansas and Oklahoma	3,390	2,999	32	---	6,421
Hawaii and Oregon	450	2,884	33	211	3,578
Iowa and Minnesota	2,050	8,051	669	188	10,958
Louisiana and Texas	135,167	14,524	1,645	333	151,669
Montana and Idaho	10,152	---	---	---	10,152
New Hampshire, Maine, Delaware	6,101	3,620	89	197	10,007
North and South Carolina	412	3,969	---	---	4,381
Utah, Nevada, Arizona	123	3	---	---	126
Total	773,766	313,915	50,247	17,857	1,155,785

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[1] Excludes 42,663 tons of lead which went directly from scrap to fabricated products and 3,690 tons of lead contained in leaded zinc oxide and other nonspecified pigments.

LEAD PIGMENTS

The lead content of pigments produced by domestic manufacturers amounted to 300,900 tons, a slight increase compared with the 299,400 tons produced in 1963. Refined pig lead was used for all except for the small amount used in leaded zinc oxide. Black oxide (battery oxides) represented 57 percent of the lead in pigments, and litharge about 31 percent. Production of basic lead sulfate is not published and lead silicate, a derivative of litharge, is included with litharge.

Consumption and Uses, White Lead.—Production of white lead, both as dry and in oil, declined, although shipments by manufacturers continued at approximately the same level as in 1963. Requirements for paint continued to decline while consumption in ceramics and other uses, including chemicals, greases, plasterizers, and stabilizers, was significantly higher.

Red Lead.—Production and shipments of red lead continued to increase. Requirements of the paint industry increased 7 percent and were well above the amount required in recent years. Other uses in lubricants, petroleum, rubber, and miscellaneous small uses also increased and remained approximately 50 percent of the total red lead.

Litharge.—Production of litharge increased about 6 percent and slightly exceeded shipments, in contrast to the large stock drawdown in 1963. Ceramics, the largest individual use, required 21 percent of the total. To avoid disclosing company confidential data, about 65 percent of the litharge shipped is incorporated into the classification "Other." Production of high lead oxide used by battery manufacturers and known as "black oxide" declined about 3 percent from the 1963 output.

Prices.—Prices of lead pigments and oxides advanced in accordance with the advance in the price of lead. The quoted price of white lead in carload lots, freight allowed, advanced from the 17.75 cents per pound established on September 9, 1963, to 19 cents on February 3 and to 20.5 cents on November 2. The average value per ton at plant was $383 dry and $519 in oil. Red lead, quoted at 16.75 cents per pound, f.o.b. works, in less than carload lots, at the beginning of the year, advanced to 17.75 cents on September 7, to 18.75 cents on October 19, and to 19.75 cents on December 28. The average value per ton at plant was $327. Litharge price held at 16.25 cents per pound, f.o.b. works, in less than carload lots, until October 19, when a 1-cent increase became effective followed by additional 1-cent increases on October 26 and December 28 and a yearend price of 19.25 cents per pound. The average value per ton at plant was $308. Total value of shipments of white lead, red lead, and litharge was $46.4 million in comparison with $38.2 million in 1963.

Foreign Trade.—Litharge imports constituted 81 percent of the total lead pigments and compounds, and receipts were about 2,700 tons less than in 1963. Increased tonnages of white lead and red lead were received and the total imports of lead pigments and compounds was about 8 percent less than those received in 1963. Exports amounted to 2,600 tons in the form of pigments and lead arsenate. The value of imports was $5.2 million; exports were valued at $0.9 million.

TABLE 16.—Production and shipments of lead pigments[1] and oxides in the United States

Pigment	1963				1964			
	Production (short tons)	Shipments			Production (short tons)	Shipments		
		Short tons	Value [2]			Short tons	Value [2]	
			Total	Average per ton [3]			Total	Average per ton
White lead:								
Dry	10,239	10,075	$3,688,456	$366	9,298	10,432	$3,997,056	$383
In oil [4]	3,758	5,327	2,485,367	467	3,298	5,014	2,600,233	519
Total	13,997	15,402	6,173,823	401	12,596	15,446	6,597,289	427
Red lead	25,780	26,245	7,391,928	282	27,812	28,090	9,172,654	327
Litharge	93,958	103,834	24,672,270	238	100,230	99,393	30,653,873	308
Black oxide	182,934				178,038			

[1] Except for basic lead sulfate, figures withheld to avoid disclosing individual company confidential data.
[2] At plant, exclusive of container.
[3] Corrected figures.
[4] Weight of white lead only, but value of paste.

TABLE 17.—Lead content of lead and zinc pigments[1] and lead oxides produced by domestic manufacturers, by sources

(Short tons)

Pigment	1963				1964			
	Lead in pigments produced from—			Total lead in pigments	Lead in pigments produced from—			Total lead in pigments
	Ore		Pig lead		Ore		Pig lead	
	Domestic	Foreign			Domestic	Foreign		
White lead	----------	----------	11,198	11,198	----------	----------	10,077	10,077
Red lead	----------	----------	23,370	23,370	----------	----------	25,212	25,212
Litharge	----------	----------	87,381	87,381	----------	----------	93,214	93,214
Black oxide	----------	----------	175,005	175,005	----------	----------	170,394	170,394
Leaded zinc oxide	1,555	869	----------	2,424	1,398	593	----------	1,991
Total	1,555	869	296,954	299,378	1,398	593	298,897	300,888

[1] Excludes lead in basic lead sulfate; figures withheld to avoid disclosing individual company confidential data.

TABLE 18.—Distribution of white lead (dry and in oil) shipments,[1] by industries

(Short tons)

Industry	1955-59 (average)	1960	1961	1962	1963	1964
Paints	17,960	14,145	12,086	12,054	11,358	10,534
Ceramics	459	219	141	137	138	143
Other	4,067	[2] 3,578	3,996	4,008	3,906	4,769
Total	22,486	17,942	16,223	16,199	15,402	15,446

[1] Excludes basic lead sulfate; figures withheld to avoid disclosing individual company confidential data.

[2] Figures for plasticizers and stabilizers withheld to avoid disclosing individual company confidential data.

TABLE 19.—Distribution of red lead shipments, by industries

(Short tons)

Industry	1955-59 (average)	1960	1961	1962	1963	1964
Paints	14,091	12,903	12,895	13,716	13,213	14,133
Storage batteries	(1)	(1)	(1)	(1)	(1)	(1)
Ceramics	(1)	328	(1)	637	(1)	(1)
Other	11,537	9,400	9,961	11,164	13,032	13,957
Total	25,628	22,631	22,856	25,517	26,245	28,090

[1] Included with "Other."

TABLE 20.—Distribution of litharge shipments, by industries

(Short tons)

Industry	1955-59 (average)	1960	1961	1962	1963	1964
Ceramics	(1)	15,753	14,393	17,752	17,762	20,508
Chrome pigments	4,390	(1)	(1)	(1)	5,763	6,426
Floor covering	(1)	(1)	(1)	(1)	(1)	(1)
Insecticides	(1)	(1)	(1)	(1)	(1)	(1)
Oil refining	3,286	2,371	2,147	2,404	1,973	2,142
Rubber	1,713	1,373	1,243	1,792	1,702	1,978
Storage batteries	(1)	(1)	(1)	(1)	(1)	(1)
Varnish	3,990	3,471	3,394	4,083	4,240	4,004
Other	103,621	75,672	77,773	77,366	72,394	64,335
Total	117,000	98,640	98,950	103,397	103,834	99,393

[1] Included with "Other."

TABLE 21.—U.S. imports for consumption of lead pigments and compounds

Kind	1963		1964	
	Short tons	Value (thousands)	Short tons	Value (thousands)
White lead	2,434	$549	2,674	$748
Red lead	1,171	198	1,613	351
Litharge	22,440	3,592	19,763	4,001
Other lead pigments	12	9	5	13
Other lead compounds	238	52	195	61
Total	26,295	4,400	24,250	5,174

Source: Bureau of the Census.

TABLE 22.—U.S. exports of lead pigments and compounds

Kind	1963		1964	
	Short tons	Value	Short tons	Value
Lead pigments [1]	1,845	$620	1,680	$608
Lead arsenate	401	135	936	278
Total	2,246	755	2,616	886

[1] Includes white lead, red lead, and litharge.

Source: Bureau of the Census.

STOCKS

The high level of demand for lead and the shortage of foreign and domestic concentrates for smelting resulted in a continued decline in stocks at primary plants. Stocks of refined lead amounted to 48,800 tons at the beginning of the year and decreased to 34,100 tons at yearend. Lead in antimonial lead decreased from 7,900 tons to 4,000 tons. Total yearend stocks representing physical inventories at primary plants regardless of ownership, but not including material in process or in transit, were 84,400 tons, a decline of 36,400 tons. The most recent comparable low for stocks was in 1955 when yearend stocks totaled 89,400 tons.

Stocks reported by the American Bureau of Metal Statistics indicate an additional 21,600 tons of lead in base bullion in process or in transit to primary plants and about 30,900 tons of lead in ores and matte in process. Total stocks of lead in metal and primary materials was thus 141,900 tons in comparison to 166,900 tons at the end of 1963.

Consumer and secondary smelter stocks of lead declined from 119,900 tons to 113,400 tons at yearend. About 61 percent of the stocks was refined lead and 31 percent was antimonial lead, a slightly higher percentage of refined lead than held in recent years.

As of December 31, 1964, the total lead inventory in all Government stockpiles was 1,338,130 tons, indicating a delivery of 40,270 tons of lead pursuant to the sale in August under Public Law 88–373.

TABLE 23.—Stocks of lead at primary smelters and refineries in the United States, Dec. 31

(Short tons)

Stocks	1955–59 (average)	1960	1961	1962	1963	1964
Refined pig lead	82,017	148,415	195,200	136,544	[r] 48,780	34,100
Lead in antimonial lead	10,815	10,483	10,354	5,975	[r] 7,890	4,012
Lead in base bullion	11,581	26,025	16,978	10,392	14,947	13,218
Lead in ore and matte	42,741	65,219	39,570	43,750	49,219	33,068
Total	147,154	250,142	262,102	196,661	120,836	84,398

[r] Revised.

TABLE 24.—Consumer stocks of lead in the United States, Dec. 31, by types of material

(Short tons, lead content)

Year	Refined soft lead	Antimonial lead	Lead in alloys	Lead in copper-base scrap	Total
1960	49,725	39,230	7,216	1,097	97,268
1961	55,951	33,633	8,298	1,258	99,140
1962	51,121	34,389	6,817	1,169	93,496
1963	71,558	40,606	6,558	1,208	119,930
1964	69,361	35,163	7,933	987	113,444

PRICES

The year opened with the quoted price of common lead at 12.5 cents per pound at New York. The price advanced almost immediately, on January 2, to 13 cents and held until August 18, when a range of 13 to 14 cents existed until firmed at 14 cents on September 1. On October 14 an increase to 15 cents was announced and on December 10 a range of 15 to 16 cents existed until firmed at 16 cents the following day. The price of 16 cents held through the end of the year. The average New York price for the year was 13.62 cents per pound.

TABLE 25.—Average monthly and yearly quoted prices of lead at St. Louis, New York, and London [1]

(Cents per pound)

Month	1963			1964		
	St. Louis	New York	London [2]	St. Louis	New York	London [2]
January	10.12	10.32	6.79	12.80	13.00	9.87
February	10.30	10.50	6.84	12.80	13.00	10.11
March	10.30	10.50	6.97	12.80	13.00	10.14
April	10.30	10.50	7.24	12.80	13.00	10.29
May	10.30	10.50	7.58	12.80	13.00	11.05
June	10.52	10.72	8.12	12.80	13.00	11.15
July	10.88	11.08	8.14	12.80	13.00	12.25
August	11.16	11.36	8.38	13.04	13.24	13.58
September	11.44	11.64	8.47	13.80	14.00	13.87
October	11.75	11.95	8.70	14.32	14.52	14.96
November	11.96	12.16	8.63	14.80	15.00	16.47
December	12.30	12.50	9.28	15.46	15.66	17.34
Average	10.94	11.14	7.93	13.42	13.62	12.59

[1] St. Louis: Metal Statistics, 1965, p. 447. New York: Metal Statistics, 1965, p. 443. London: E&MJ Metal and Mineral Markets.

[2] Based on monthly rates of exchange by Federal Reserve Board.

Quotation on the London Metal Exchange gradually climbed from a low of £76.88 per long ton in January (equivalent to 9.6 cents per pound, U.S. currency, computed on the average monthly rate of exchange) to a high of £154 (19.2 cents) on December 15 and closed the year at £122 (15.2 cents). The average for the year was 12.6 cents per pound (U.S. equivalent).

FOREIGN TRADE

Receipts of lead materials as general imports amounted to 341,000 tons, a 12-percent decrease, and continued the decline in imports initiated in 1962. Primary materials for domestic smelting and refining totaled 128,100 tons, 16-percent less than had been received in 1963. Imports of metal amounted to 207,800 tons, an 8-percent decrease; scrap receipts also decreased. Imports for consumption of materials for domestic processing totaled 135,100 tons and imports of metal amounted to 211,140 tons. The primary raw materials entered under the quota amounted to 90 percent of the allowable limitation for the year, while the quota for lead metal was essentially filled in each quarter. Imports for consumption of scrap decreased as did semifabricated products such as sheet, pipe, and shot.

The major suppliers of ore in descending order of importance were Peru, Republic of South Africa, Canada, Australia, Bolivia, and Mexico. Mexico supplied 34 percent of the metal, followed by Australia, Canada, Yugoslavia, and Peru.

TABLE 26.—U.S. imports [1] of lead, by countries

(Short tons)

Country	1955–59 (average)	1960	1961	1962	1963	1964
Ore, flue dust, and matte (lead content):						
North America:						
Canada	28,694	26,473	34,361	27,728	23,634	27,951
Guatemala	5,250	1,809	9,817	2,135	305	5
Honduras	3,180	4,906	5,512	4,965	6,809	6,375
Mexico	2,435	1,249	1,166	1,180	1,071	1,069
Other	1,128					
Total	40,687	34,437	50,856	36,008	31,819	35,400
South America:						
Bolivia	15,049	9,021	11,370	8,242	9,791	6,073
Chile	208	1,283	610			
Colombia	682	705	722	439	9	
Peru	52,537	36,300	28,970	32,999	43,950	28,243
Other	308	103				
Total	68,784	47,412	41,672	41,680	53,750	34,316
Europe	151	222	300	280		
Asia:						
Philippines	1,424	228	238	57	23	58
Other	202	504		181	244	117
Total	1,626	732	238	238	267	175
Africa:						
South Africa, Republic of	41,359	39,352	34,089	33,881	34,273	34,080
Other	5	5,238				
Total	41,364	44,590	34,089	33,881	34,273	34,080
Oceania: Australia	29,956	18,299	20,031	26,544	27,633	19,286
Total ore, flue dust, and matte	182,568	145,692	147,186	138,631	147,742	123,257

See footnotes at end of table.

TABLE 26.—U.S. imports [1] of lead, by countries—Continued

(Short tons)

Country	1955-59 (average)	1960	1961	1962	1963	1964
Base bullion (lead content):						
North America	15	254	362	5	851	1,449
South America	116	39	60	2,080	2,647	603
Europe			(2)		2	
Asia	(2)					
Oceania				2,514	1,937	2,786
Total base bullion	131	293	422	4,599	5,437	4,838
Pigs and bars (lead content):						
North America:						
Canada	32,348	26,088	54,717	56,807	29,619	30,728
Mexico	96,621	69,930	81,328	65,892	74,466	71,728
Other	65	9	3			114
Total	129,034	96,027	136,048	122,699	104,085	102,570
South America:						
Peru	32,966	25,197	26,195	22,115	23,486	24,510
Other	350				36	
Total	33,316	25,197	26,195	22,115	23,522	24,510
Europe:						
Belgium-Luxembourg	2,133	610		2,980	11,235	
Denmark	2,473					700
Germany, West	1,645	551	842	914	277	5,017
Spain	8,820	4,115	8,529	4,104	7,694	949
United Kingdom	2,530	7		335	3,555	562
Yugoslavia	36,868	30,027	30,347	31,909	31,063	30,544
Other	349	1,388		12		834
Total	54,818	36,698	39,718	40,254	53,824	38,606
Asia	11					
Africa	7,633	1,328				
Oceania: Australia	71,778	46,783	54,891	72,133	45,596	42,158
Total pigs and bars	296,590	206,033	256,852	257,201	227,027	207,844
Reclaimed, scrap, etc. (lead content):						
North America:						
Canada	4,043	4,059	1,441	1,279	3,243	1,959
Mexico	4,327	1,054	2,294	688	55	164
Other	849	160	45	186	162	46
Total	9,219	5,273	3,780	2,153	3,460	2,169
South America:						
Peru	103					
Venezuela	377					
Other	35					
Total	515					
Europe:						
Belgium-Luxembourg	140					
Denmark	273					
Germany, West	104	1		(2)	1	
Netherlands	54			17	12	
Other	155	4	2			
Total	726	5	2	17	13	
Asia	14	5		2		
Oceania: Australia	2,602	2,355	1,160	149	5,402	2,885
Total reclaimed, scrap, etc	13,076	7,638	4,942	2,321	8,875	5,054
Grand total	492,365	359,656	409,402	402,752	389,081	340,993

[1] Data are general imports; that is, they include lead imported for immediate consumption plus material entering the country under bond.

[2] Less than ½ unit.

Source: Bureau of the Census.

TABLE 27.—U.S. imports for consumption[1] of lead, by countries

(Short tons)

Country	1955–59 (average)	1960	1961	1962	1963	1964
Ore, flue dust, and matte (lead content):						
North America:						
Canada	31,645	27,944	31,439	29,523	r 30,937	27,973
Guatemala	5,152	1,519	5,527	4,691	387	5
Honduras	3,410	4,457	4,803	5,959	8,692	6,489
Mexico	2,964	943	1,060	1,899	1,850	458
Other	1,063	---	---	---	---	---
Total	44,234	34,863	42,829	42,072	r 41,866	34,925
South America:						
Bolivia	15,420	10,581	10,470	7,479	10,055	8,373
Chile	2,114	27	401	3	---	---
Colombia	696	628	514	480	95	---
Peru	56,410	33,571	32,318	32,327	32,140	32,314
Other	294	103	---	3	---	---
Total	74,934	44,910	43,703	40,292	42,290	40,687
Europe	30	(2)	---	220	---	---
Asia:						
Philippines	1,428	187	380	111	31	86
Other	166	427	---	---	223	121
Total	1,594	614	380	111	254	207
Africa:						
South Africa, Republic of	39,129	30,784	29,736	29,756	29,740	29,760
Other	371	5,238	---	2	---	---
Total	39,500	36,022	29,736	29,758	29,740	29,760
Oceania:						
Australia	30,977	20,894	20,132	20,627	21,295	22,488
Other	32	---	---	---	---	---
Total	31,009	20,894	20,132	20,627	21,295	22,488
Total ore, flue dust, and matte	191,301	137,303	136,780	133,080	r 135,445	128,067
Base bullion (lead content):						
North America	15	254	134	5	964	3,094
South America	86	39	102	2,078	854	603
Europe	---	---	(2)	---	3	560
Oceania	---	---	---	---	1,937	2,786
Total base bullion	101	293	236	2,083	3,758	7,043
Pigs and bars (lead content):						
North America:						
Canada	32,337	26,154	54,902	56,807	29,674	30,777
Mexico	93,893	73,748	71,289	68,147	78,254	72,078
Other	52	29	6	---	---	45
Total	126,282	99,931	126,197	124,954	107,928	102,900
South America:						
Peru	32,955	25,197	26,195	22,103	22,224	23,114
Other	349	---	---	---	35	---
Total	33,304	25,197	26,195	22,103	22,259	23,114
Europe:						
Belgium-Luxembourg	1,892	1,733	41	1,685	4,366	4,375
Denmark	1,448	88	---	---	---	700
Germany, West	1,567	654	911	614	577	3,692
Spain	8,249	6,056	8,775	3,958	7,713	847
United Kingdom	2,484	133	16	---	1,462	1,697

See footnotes at end of table.

TABLE 27.—U.S. imports for consumption[1] of lead, by countries—Continued

(Short tons)

Country	1955-59 (average)	1960	1961	1962	1963	1964
Pigs and bars (lead content)—Continued						
Europe—Continued						
Yugoslavia	36,797	30,159	30,230	32,240	31,063	30,544
Other	997	1,877	---	12	---	834
Total	53,434	40,700	39,973	38,509	45,181	42,689
Asia	11	---	---	---	---	---
Africa:						
Morocco	7,408	1,243	4	---	---	---
Other	456	460	113	---	---	---
Total	7,864	1,703	117	---	---	---
Oceania: Australia	71,561	45,816	54,945	72,300	45,030	42,437
Total pigs and bars	292,456	213,347	247,427	257,866	220,398	211,140
Reclaimed, scrap, etc. (lead content):						
North America:						
Canada	4,044	4,053	1,441	1,240	3,218	1,716
Mexico	4,802	1,189	2,291	612	55	164
Other	886	220	91	58	288	26
Total	9,732	5,462	3,823	1,910	3,561	1,906
South America:						
Peru	149				903	---
Venezuela	377	---	---	---	---	---
Other	41	---	---	---	---	---
Total	567	---	---	---	903	---
Europe:						
Belgium-Luxembourg	140	---	---	---	---	---
Denmark	273	---	---	---	---	---
Germany, West	160	1	---	(2)	(2)	1
Netherlands	54	---	---	17	12	---
Other	190	15	2	---	---	---
Total	817	16	2	17	12	1
Asia	13	5	1	2	---	---
Oceania:						
Australia	1,560	115	68	149	10,929	---
Other	11	---	---	---	---	---
Total	1,571	115	68	149	10,929	---
Total reclaimed, scrap, etc	12,700	5,598	3,894	2,078	15,405	1,907
Sheets, pipe, and shot:						
North America:						
Canada	253	213	114	49	35	78
Canal Zone	4	---	---	---	---	---
Mexico	2,690	---	55	---	---	---
Total	2,947	213	169	49	35	78
Europe	1,423	2,641	2,639	2,197	2,389	1,445
Asia	(2)	1	37	30	5	(2)
Total sheets, pipe and shot	4,370	2,855	2,845	2,276	2,429	1,523
Grand total	500,928	359,396	391,182	397,383	[r] 377,435	349,680

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[r] Revised.

[1] Excludes imports for manufacture in bond and export, classified as "imports for consumption" by the Bureau of the Census.

[2] Less than ½ unit.

Source: Bureau of the Census.

TABLE 28.—U.S. imports for consumption of lead, by classes [1]

Year	Lead in ore, flue dust or fume, and mattes, n.s.p.f. (lead content)		Lead in base bullion (lead content)		Pigs and bars (lead content)		Reclaimed, scrap, etc. (lead content)		Sheets, pipe, and shot		Not otherwise specified value (thousands)	Total value (thousands)
	Short tons	Value (thousands)	Short tons	Value (thousands)	Short tons	Value (thousands)	Short tons	Value (thousands)	Short tons	Value (thousands)		
1955-59 (average)	191,301	$45,771	101	$35	292,456	$72,393	12,700	$2,717	4,370	$1,075	$348	$122,339
1960	137,303	27,816	293	62	213,347	45,065	5,598	1,034	2,855	696	710	75,383
1961	136,780	24,332	236	51	247,427	45,881	3,894	592	2,845	641	807	72,304
1962	133,080	21,003	2,083	710	257,866	41,570	2,078	269	2,276	474	978	65,004
1963	[r]135,445	[r]21,534	3,758	1,792	220,398	[r]40,126	15,405	2,009	2,429	513	792	[r]66,766
1964	128,067	21,789	7,043	2,058	211,140	45,790	1,907	350	1,523	369	713	71,069

[r] Revised.

[1] Excludes imports for consumption in bond and export, classified as "imports for consumption" by the Bureau of the Census.

Source: Bureau of the Census.

TABLE 29.—U.S. imports for consumption of miscellaneous products containing lead

Year	Babbitt metal, solder, white metal, and other combinations containing lead			Type metal and antimonial lead		
	Gross weight (short tons)	Lead content (short tons)	Value (thousands)	Gross weight (short tons)	Lead content (short tons)	Value (thousands)
1955-59 (average)	5,195	2,342	$5,967	8,036	7,223	$2,212
1960	9,274	1,512	16,024	4,560	3,915	970
1961	7,930	1,409	14,207	6,430	5,765	1,340
1962	2,438	1,030	3,443	8,576	7,512	1,393
1963	2,535	1,246	3,207	[1] 3,747	[1] 3,196	[1] 621
1964	3,425	1,619	5,785	NA	NA	NA

NA Not available.

[1] Due to changes in classification, effective Sept. 1, 1963, data no longer separately classified. January–August data tabulated.

Source: Bureau of the Census.

TABLE 30.—U.S. exports of lead, by countries[1]

(Short tons)

Destination	1955–59 (average)	1960	1961	1962	1963	1964
Ore, matte, base bullion (lead content):						
North America:						
Canada	15	16	3	--------	--------	--------
Mexico	848	107	--------	--------	--------	--------
Other	--------	--------	--------	--------	4	--------
Total	863	123	3	--------	4	--------
South America	--------	--------	--------	--------	--------	12
Europe	6	--------	77	7	--------	--------
Asia	37	1,174	4,357	2,891	--------	7
Total, ore, matte, base bullion	906	1,297	4,437	2,898	4	19
Pigs, bars, anodes:						
North America:						
Canada	69	24	80	39	112	104
Cuba	42	10	--------	--------	--------	--------
Mexico	14	60	24	25	23	10
Other	90	149	39	66	95	209
Total	215	243	143	130	230	323
South America	171	18	794	588	188	105
Europe	542	30	3	28	153	7,330
Asia:						
Japan	697	--------	--------	--------	--------	553
Philippines	325	34	227	81	26	130
Taiwan	542	1,536	874	950	--------	575
Other	203	103	78	321	478	1,115
Total	1,767	1,673	1,179	1,352	504	2,373
Africa	2	2	12	9	10	33
Oceania	--------	1	2	1	3	11
Total pigs, bars, anodes	2,697	1,967	2,133	2,108	1,088	10,175
Scrap:						
North America	5	1,220	54	37	14	400
South America	(2)	2	2	15	8	--------
Europe:						
Belgium-Luxembourg	155	6	688	328	1,182	1,566
Germany, West	333	129	253	119	498	632
Italy	19	74	162	289	--------	15
Netherlands	371	297	251	159	72	296
United Kingdom	491	851	1,167	786	519	1,293
Other	96	--------	--------	116	41	3,097
Total	1,465	1,357	2,521	1,797	2,312	6,899
Asia:						
Japan	162	--------	2,579	593	85	5,847
Other	(2)	(2)	7	19	2	2
Total	162	(2)	2,586	612	87	5,849
Total scrap	1,632	2,579	5,163	2,461	2,421	13,148
Grand total	5,235	5,843	11,733	7,467	3,513	23,342

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[1] In addition foreign lead was reexported as follows: Ore, matte, and base bullion 1955–59 (average) 2 tons; 1960–64 none. Pigs, bars, anodes, 1955–59 (average) 91 tons; 1960, none; 1961, 294 tons; 1962–63, none; 1964, 4,367 tons. Scrap, 1955–59 (average) 2 tons; 1960–64, none.

[2] Less than ½ unit.

Source: Bureau of the Census.

WORLD REVIEW

World mine production of lead in 1964 declined to less than 2.7 million tons; decreases were indicated for South America, Europe, and, especially, Africa. Smelter production increased for all areas except Africa and Australia. Lead consumption, according to the American Bureau of Metal Statistics, continued to increase substantially with the 1964 free world above 2.3 million tons, a gain of some 374,000 tons or 19 percent since 1959.

Demand for lead metal and, especially, for lead in concentrates continued strong throughout the year and the average monthly London Metal Exchange price for lead increased each month to a high of £139.2 in December. New York price likewise increased from 12.5 cents at the close of 1963 to 16 cents per pound at the close of 1964. World producer stocks, as published by the International Lead and Zinc Study Group, declined from 228,000 tons to 185,000 tons. Of this Europe held 50,000 tons; the United States, 50,000; and other countries, 85,000.

The strong demand and price of lead, along with improvement in market for associated metals, induced a substantial increase in exploration, development, and planned expansion of old mines and construction of new plants throughout the world. Some additional lead from these projects will be forthcoming in 1965, but the major increases will not become available until after mid-1966.

TABLE 31.—World mine production of lead (content of ore) recoverable where indicated, by countries [1] [2]

(Short tons)

Country	1955–59 (average)	1960	1961	1962	1963	1964 [p]
North America:						
Canada	[3] 189,295	[3] 205,650	[4] 182,557	[4] 211,321	[4] 198,988	[4] 206,359
Cuba	73	---	---	---	---	---
Greenland	[5] 8,627	7,635	10,104	891	---	---
Guatemala [3]	8,351	9,432	9,458	1,067	825	[e] 220
Honduras	3,042	5,913	6,762	6,522	[6] 10,913	[e] 500
Mexico	224,409	210,177	199,877	213,074	209,425	187,345
United States [3]	310,406	246,669	261,921	236,956	253,369	286,010
Total	744,203	685,476	670,679	669,831	673,520	680,434
South America:						
Argentina	30,754	29,432	31,306	32,606	28,991	28,264
Bolivia (exports)	23,589	23,610	22,403	20,504	22,226	19,491
Brazil [e]	6,200	12,200	15,400	16,800	19,200	[7] 19,200
Chile	3,317	2,694	2,252	1,603	957	1,230
Colombia (U.S. imports)	681	705	722	439	9	---
Ecuador	118	119	122	137	179	153
Peru [3]	139,851	145,097	150,353	141,290	163,468	164,508
Total	204,510	213,857	222,558	213,379	235,030	232,846
Europe:						
Austria [3]	5,691	5,758	6,051	5,855	5,504	5,727
Bulgaria	70,618	92,341	88,229	104,058	97,995	100,641

See footnotes at end of table.

TABLE 31.—World mine production of lead (content of ore) recoverable where indicated, by countries [1] [2]—Continued

(Short tons)

Country	1955–59 (average)	1960	1961	1962	1963	1964 [p]
Europe—Continued						
Czechoslovakia [e]	6,500	7,200	7,200	14,900	14,900	14,900
Finland	1,928	1,755	3,439	3,161	1,262	2,083
France	13,289	20,451	20,785	15,735	9,255	13,007
Germany:						
East [e]	7,300	7,700	7,700	8,300	8,300	8,300
West	70,316	54,919	54,453	54,710	57,143	53,926
Greece	8,731	10,141	12,787	14,110	[e] 14,550	15,873
Ireland	1,808	1,480	279	--------	--------	--------
Italy	58,118	54,525	52,216	45,463	36,266	36,333
Norway	1,499	2,780	2,524	3,417	3,858	3,968
Poland	37,016	43,211	42,108	41,778	42,659	42,329
Portugal	1,106	34	28	49	247	220
Rumania [e] [8]	13,000	13,200	13,200	13,800	13,800	14,000
Spain	72,327	80,353	87,863	78,262	68,557	63,231
Sweden	42,334	60,963	70,518	74,721	75,729	71,871
U.S.S.R. [e] [8]	310,000	350,000	390,000	390,000	390,000	400,000
United Kingdom	[3] 6,597	1,549	1,656	446	276	198
Yugoslavia	99,161	100,554	106,572	112,430	111,970	111,989
Total [e]	827,300	908,900	967,600	981,200	952,300	958,600
Asia:						
Burma	19,031	19,070	18,519	22,377	28,784	20,889
China [e]	49,600	88,000	99,000	99,000	110,000	110,000
India	3,890	4,991	4,478	5,065	4,758	4,966
Iran [e] [9]	18,500	16,500	16,500	11,000	11,000	[e] 16,500
Japan	36,290	43,577	51,015	58,924	58,110	59,611
Korea:						
North [e]	41,000	55,000	55,000	55,000	55,000	55,000
South	993	1,012	1,014	1,558	2,113	3,713
Philippines	1,523	134	111	90	78	114
Thailand	3,223	2,028	2,437	2,600	2,496	4,030
Turkey	2,215	1,830	3,538	4,299	2,811	1,792
Total [e]	176,300	232,100	251,600	259,900	275,200	276,600
Africa:						
Algeria	11,602	11,529	10,337	9,964	8,841	10,525
Congo, Republic of (Brazzaville)	3,609	4,741	1,634	368	364	[e] 2,400
Morocco	100,048	104,444	97,299	99,323	81,540	77,636
Nigeria	309	223	7	--------	--------	--------
South Africa, Republic of	581	136	103	7	17	--------
South-West Africa [10]	87,983	71,540	69,997	82,688	80,878	[e] 45,200
Tanzania (exports)	5,320	6,927	387	--------	--------	--------
Tunisia	25,306	19,986	19,123	14,936	15,697	14,794
Uganda (exports)	110	--------	--------	--------	--------	--------
United Arab Republic (Egypt) [e]	331	88	39	595	[e] 550	--------
Zambia [8]	16,505	16,161	16,999	16,343	21,615	14,508
Total	251,704	235,775	215,925	224,224	209,502	165,063
Oceania: Australia	352,208	345,143	302,019	414,524	459,568	419,852
World total [e]	2,555,000	2,620,000	2,630,000	2,765,000	2,805,000	2,735,000

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[e] Estimate. [p] Preliminary.

[1] Data derived in part from United Nations Statistical Yearbook, Yearbook of the American Bureau of Metal Statistics, and annual issues of the Statistical Summary of the Mineral Industry (Overseas Geological Surveys, London), and Metal Statistics (Metallgesellschaft) Germany.

[2] This table incorporates some revisions. Data do not add exactly to totals shown because of rounding where estimated figures are included in the detail.

[3] Recoverable.

[4] Data for 1961, 1962, 1963, and 1964 not strictly comparable to previous years.

[5] Average annual production 1956–59.

[6] Exports.

[7] 1963 data.

[8] Smelter production.

[9] Year ended March 21 of year following that stated.

[10] Includes lead content of lead-vanadium concentrates.

TABLE 32.—World smelter production of lead, by countries [1] [2]

(Short tons)

Country	1955–59 (average)	1960	1961	1962	1963	1964 [p]
North America:						
Canada	143,756	160,079	172,365	152,743	[r] 155,881	151,479
Guatemala	[e] 33	200	62	69	52	[e] 220
Mexico	218,919	205,263	194,476	208,447	205,217	183,758
United States (refined) [3]	473,001	382,436	449,486	376,024	394,732	449,429
Total	835,709	747,978	816,389	737,283	755,882	784,886
South America:						
Argentina	29,100	28,300	30,865	27,000	26,455	25,353
Bolivia (exports) [4]	1,524	119	4	138	--------	18
Brazil	5,738	10,997	13,865	15,090	17,243	[5] 17,243
Chile	354	661	529	280	243	--------
Peru	68,761	81,726	84,253	75,356	91,577	98,904
Total	105,477	121,803	129,516	117,864	135,518	141,518
Europe:						
Austria [6]	13,098	13,717	13,605	13,417	10,783	9,365
Belgium [6]	103,311	102,190	110,110	102,681	108,507	91,840
Bulgaria	19,621	44,540	45,099	48,171	56,584	96,452
Czechoslovakia [e]	9,700	10,000	10,000	15,400	15,400	15,400
France [6]	75,898	81,998	78,052	77,787	85,723	98,970
Germany:						
East [e] [6]	27,000	27,500	27,500	28,700	28,700	28,700
West	142,355	162,772	155,008	163,665	154,032	118,486
Greece	3,805	3,407	3,267	3,300	3,858	5,512
Italy	46,945	45,912	47,411	46,282	46,228	41,787
Norway	--------	--------	--------	--------	--------	4,409
Poland	39,597	43,762	43,874	44,842	42,895	45,746
Portugal	892	998	1,663	2,227	1,232	1,268
Rumania [e]	13,000	13,200	13,200	13,800	13,800	14,000
Spain	71,766	78,464	85,678	79,666	68,436	60,698
Sweden	30,688	49,112	42,745	42,737	45,000	44,754
U.S.S.R. [e] [6]	310,000	350,000	390,000	390,000	390,000	400,000
United Kingdom	5,679	1,224	1,178	614	297	195
Yugoslavia	88,086	98,263	99,650	107,945	114,832	111,427
Total [e]	1,001,400	1,127,100	1,168,000	1,181,200	1,186,300	1,189,000
Asia:						
Burma	21,200	18,499	17,376	19,164	19,553	19,900
China [e]	37,000	77,000	95,000	95,000	99,000	110,000
India	3,391	4,128	4,039	3,140	3,899	3,995
Iran [7]	1,151	1,279	1,437	441	[e] 550	[e] 550
Japan	52,229	76,465	83,476	96,735	101,575	119,006
Korea: North [e]	17,000	33,000	45,000	45,000	45,000	45,000
Turkey [e]	298	518	698	702	2,073	1,279
Total [e]	132,300	210,900	247,000	260,200	271,700	299,700
Africa:						
Morocco	32,547	33,871	26,993	26,613	20,679	20,766
South-West Africa	--------	--------	--------	--------	1,997	52,685
Tunisia [4]	26,780	21,894	20,307	17,447	14,110	12,634
Zambia	16,525	16,161	16,999	16,343	21,615	14,508
Total	75,852	71,926	64,299	60,403	58,401	100,593
Oceania: Australia:						
Refined lead	213,232	212,603	181,736	212,941	251,558	227,485
Pb content of lead bullion (for export)	52,287	59,050	53,861	81,883	90,341	84,289
Total	265,519	271,653	235,597	294,824	341,899	311,774
World total [e]	2,415,000	2,550,000	2,660,000	2,650,000	2,750,000	2,830,000

[e] Estimate. [p] Preliminary.

[1] Data derived in part from United Nations Statistical Yearbook, Yearbook of the American Bureau of Metal Statistics, and annual issues of Statistical Summary of the Mineral Industry (Overseas Geological Surveys, London), Metal Statistics (Metallgesellschaft) Germany and The International Lead and Zinc Study Group.

[2] This table incorporates some revisions. Data do not add exactly to totals shown because of rounding where estimated figures are included in the detail.

[3] Figures cover lead refined from domestic and foreign ores; refined lead produced from foreign base bullion not included.

[4] Lead bars only; does not include lead contained in antimonial lead or in solders.

[5] 1963 data.

[6] Includes scrap.

[7] Year ended March 21 of year following that stated.

NORTH AMERICA

Canada.—Mine production of lead decreased to 200,300 tons of recoverable lead compared with 201,200 tons in 1963. The output of lead, both refined and contained in unrefined products, entirely from the Consolidated Mining and Smelting Co. of Canada, Ltd. (COMINCO), smelter and refinery at Trail, British Columbia, was 151,500 tons compared with 155,900 tons in 1963. Lead in concentrates surplus to smelter requirements were exported to the United States, Belgium, West Germany, France, and Japan. Exports of refined lead were relatively unchanged with the United Kingdom, United States, Japan, and India receiving the metal.[2]

Mines situated in British Columbia supplied 67 percent of the lead produced in Canada. COMINCO operated three mines: Sullivan, H. B., and Bluebell. Reeves MacDonald Mines, Ltd., operated its mine and mill near Salmo and Canadian Exploration, Ltd., operated the Jersey mine and mill in the Salmo vicinity. The Mineral King mine of Sheep Creek Mines, Ltd., in the Windermere district, and the Mastodon-Highland Bell Mines, Ltd., mine near Penticton were in normal operation throughout the year.

The United Keno Hill Mines, Ltd., expanded lead production in the Yukon Territory in 1964. Three mines, Calumet, Hector, and Elsa, were the principal producers. Two other mines, Keno and No Cash, were under development. Construction and development of the Pine Point mine south of Great Slave Lake, by COMINCO, continued toward completion of the open-pit development, concentrating plant, and powerplant late in 1965. The laying of rails on the 425-mile Canadian National Railway to Pine Point was completed late in the year, and test shipments of ore to the Trail, British Columbia, plant started. At the end of the year the ore reserve was adjusted upward to an estimated 17.5 million tons averaging 4.8 percent lead and 7.4 percent zinc.

Hudson Bay Mining and Smelting Co., Ltd., produced zinc-lead-copper ore at the Chisel Lake mine in Manitoba and treated the ore at the Flin Flon mill to produce a lead concentrate for shipment to a custom smelter. The mines at Manitouwadge, Ontario, owned by Geco Mines, Ltd., and Willroy Mines, Ltd., produced about 2,000 tons of lead in concentrates. Production of lead in Quebec remained small and was essentially a byproduct of the several zinc and copper mines operating in the province.

The Atlantic provinces of Newfoundland and New Brunswick each produced about 12 percent of the Canadian production. The Buchans unit of American Smelting and Refining Company operated the only mine and mill in Newfoundland and exported the concentrates for refining. The Brunswick Mining and Smelting Corp., Ltd., brought its No. 12 mine near Bathurst into production in March and by September the mill was treating 4,500 tons of ore daily. The lead and zinc concentrates were shipped to European smelters pending completion of an Imperial Smelting Corp. zinc-lead blast furnace in mid-1966, with initial production scheduled at 30,000 tons of lead annually. Lead and zinc concentrates were also produced by Magnet Cove Barium Corp., Ltd., at Walton, Nova Scotia.

The Consolidated Mining & Smelting Co. of Canada, Ltd. Annual Report, 1964, p. 6.

Mexico.—The greater marketing opportunities for base metal and silver and resulting higher prices stimulated a revival of activity in many of the small mines for which Mexico is noted. In order to assist these operators, the Comision de Fomento Minero started buying ore in the Parral, Chihuahua, area and was investigating the potential of a custom mill. Mixed lead-zinc concentrate of 25 percent lead and 30 percent zinc from the Sonora area was marketed for the first time with sales made in Canada.

Cia. Mexicana Penoles, S.A., operated three underground mining units; Avalos, the largest, is situated at Terminal in Zacatecas; Calabaza is in Jalisco, in the southwest; and Topia is in Durango, in west-central Mexico. Lead concentrates were shipped to the custom smelter of the affiliated Cia. Metalurgica Penoles, S.A., at Torreon, and the bullion is then shipped to the Penoles refinery at Monterrey. In November, Productora de Minerales, S.A., began the reopening of the Cedral lead-zinc mine in the State of San Luis Potosi which is held under lease from American Smelting and Refining Co.

Compania Minera Asarco, S.A., the subsidiary of American Smelting and Refining, operated its mining properties and metallurgical plants at a satisfactory level during the year. Mine development was accelerated at the Santa Barbara, Plomosas, Taxco, and Parral mines. Ore depletion at the Neustra Senora mine during the year resulted in plans for closure of the mine. About 35 percent of the lead metal produced at the Monterrey smelter was sold for consumption in Mexico and the remainder exported.[3]

San Francisco Mines of Mexico, Ltd., Minera Frisco, S.A., in the fiscal year to June 30, 1964, reported a small decrease in production in relation to the 1963 period and grade of ore was lower. The rate of development was increased to counteract depletion of ore reserves in recent years. American Metal Climax, Inc., acquired from San Francisco Mines of Mexico, Ltd., a substantial interest in the mine during the year.[4] Compania Fresnillo, S.A., operated the following mine and concentration plants: Fresnillo unit, Zacatecas; Naica unit, Chihuahua; and the Zimapan mine with the ore treated by a custom mill. Production at both the Fresnillo and Naica units was at a somewhat higher rate than the previous period, and the reserves of sulfide ore exceeded 4.5 million tons averaging 5 percent lead. Production of lead in concentrates by the company was slightly below 48,000 tons.[5]

SOUTH AMERICA

Argentina.—Cia. Minera Aguilar, S.A., a subsidiary of St. Joseph Lead Co., was the principal producer and operated at a high level during the year. Concentrates were exported for smelting and refining. Cia. Minera Castano Viejo, S.A., controlled by National Lead Company, S.A. (a subsidiary of National Lead Co.), resumed production after a major exploration program developed additional ore on the main Castano vein.

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[3] American Smelting and Refining Co. Annual Report, 1964, p. 14.

[4] American Metal Climax, Inc. Annual Report, 1964, p. 14.
San Francisco Mines of Mexico, Ltd. Annual Report, 1964, p. 5.

[5] The Fresnillo Co. Annual Report, 1964, p. 12.

Bolivia.—Corporación Minera de Bolivia operated the nationalized mines of which the Animas mine was the largest lead producer, followed by the Tatasi mine and the San José mine. Several small mines produced ore for which the Mining Bank of Bolivia (Banco Minero) acted as agent.

Brazil.—Cia. Brasileira de Chumbo, controlled by Cia. Accumuladores Prest-O-Lite, operated two mines—Mineracão Boquira, Ltd., in the State of Bahia, and Cia. Plumbum, S.A., in Parana. The recently discovered deposits of lead in Bahia produce some two-thirds of total output which is smelted at the company's plant in Santo Amaro, while a smaller smelter in Panelas, Parana, services the Plumbum operation.

Chile.—Lead was produced by two companies: Sucesion Frederico Blanc, which produced a small tonnage of metal at its "Dos Rios" smelter in Coquimbo Province, and Empresa Minera Aisén (formerly Cia. Minera Aisán) which operated a mine on the north side of Lake Buenos Aires. Ores and concentrates were exported to Europe.

Peru.—Cerro de Pasco Corp., the operating subsidiary of Cerro Corp., established a production record of almost 98,600 tons of lead in 1964 of which 58 percent came from its mines and 42 percent from purchased ores. Initial steps were taken in 1964 to expand lead-zinc production from the McCune pit at the Cerro de Pasco mine and preparations were made to sink a new 1,850-foot production shaft.[6]

Other major producers of lead concentrate included Cia. Minerales Santander, Inc., a subsidiary of St. Joseph Lead Co.; Northern Peru Mining Co., a subsidiary of American Smelting and Refining; Cie. des Mines de Huaron, a French controlled company; Cia. Minera Atacocha, S.A.; Cia. Minera Milpo, S.A.; Sociedad Minera "El Brocal"; Volcan Mines Co.; Sindicato Minera Rio Pallanga; Cia. Minera Santo Toribio, S.A.; and Sociedad Minera Yauli. As the La Oroya plant of Cerro de Pasco was the only smelter in Peru, the companies either sold concentrate to Cerro de Pasco or exported it to foreign smelters. The Mining Bank of Peru (Banco Minera del Peru) acted as agent for several of the small mines.

EUROPE

Bulgaria.—The Plovdiv Non-ferrous Metals Combine expanded lead production from the new metallurgical works which were on stream in late October 1963. The No. 2 blast furnace began production in mid-1964. Lead refining uses a newly developed Russian continuous decopperizing process employing a rectangular furnace containing a bath of molten lead and surface temperature of 1,200° C. Decopperized bullion is removed by underflow at 420° C and copper as a 45 to 55 percent copper matte. Lead concentrates ranging from 40 to 70 percent lead were supplied by mines at Gorubso, Chiprovtsi, Madjarovo, and Ustrem.

Finland.—The Aijala mine produced lead concentrates containing about 600 tons of lead and installed a new system of grinding and flotation in the concentrator late in the year. The Vihante mine, principally a zinc producer, yielded some 1,200 tons of lead in concentrates.

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[6] Cerro Corp. Annual Report, 1964, p. 3.

Unwatering of the Korsnas mine and installation of concentrating equipment was completed and production resumed in December.

Greece.—Two plants for concentrating lead and zinc ore were in operation; one at Laurium, Attica, and the other at Kassandra, Chalkidiki. All concentrates were exported. Investigation of an Imperial-type furnace was in progress to smelt ores of the Kassandra, Laurium, and Kirki areas. Mineral research on state-owned deposits at Kirki near Alexandroupolis, Thrace, was initiated by the Institute of Geology and Subsurface Research.

Sweden.—Boliden Gruvaktubolag, A.B., announced plans to develop a new lead-zinc mine at Langdal. The completion schedule was 1967 in order to replace the nearby depleted Boliden mine.

United Kingdom.—Consolidated Gold Fields, Ltd., conducted exploration at Strontian in western Scotland. The last lead production from the area was in 1871 terminating some 80 years of production. Glebe Mines, Ltd., was developing a new fluorspar-lead mine in the Derbyshire area. The district was worked over a hundred years ago for lead and then closed for a long period. From 1940–64 the mines have been worked mainly for fluorspar but have produced about 2,000 tons of lead concentrates annually.

ASIA

Japan.—Nippon Mining Company, Ltd., expanded production of lead-zinc ore from the Toyoha mine in Hokkaido. A new company, the Sumitomo ISP Co., was formed to construct and operate a concentrating plant and Imperial-type smelter in the Hyogo Prefecture. The smelter was scheduled to begin operation early in 1966.

Turkey.—The Kaleköy mine in the Zámante River district produced hand-cobbed, high-grade sulfide ore. Kursun Sanyaii, Ltd., operated the Karacoga mine and concentrated the ore at the flotation plant in Simav and also operated a small smelter at Darica. The Keban mine operated by Etibank, the State Mining Enterprise, was the principal producer. The ore was concentrated by flotation and the lead and zinc concentrates smelted abroad and sold in the domestic market as refined metal.

AFRICA

Algeria.—Five lead and zinc mines were operative during 1964 with the greatest part of total production coming from the mines at El Abed and Oued Zounder near the Moroccan frontier. The El Abed mine was becoming exhausted of commercial grade ore and, while production increased in 1964, it was expected to trend downward.

Morocco.—Lead production came from 12 active mines operated by 10 individual companies. The concentrates were exported for smelting except those shipped to the Ourd-el-Heimer smelter owned jointly by Société des Mines de Zellidja and Société Minère et Métallurgique de Penarroya.

South-West Africa.—Newmont Mining Corp. reported that during the fiscal year ending June 30, 1964, a total of 748,200 tons of ore, averaging 12.66 percent lead, 4.02 percent copper, and 3.75 percent zinc, was mined and milled at the Tsumeb plant and 272,700 tons of ore, averaging 3.99 percent copper and 1.41 percent lead, was mined and milled at the Kombat plant.[7]

Tunis.—Six major lead-zinc mines were active in 1964. Three of the mines were under national control while the other three continued under individual companies. Production continued on the same level as in 1963. A Yugoslav firm has contracted to design and construct a lead-zinc flotation plant at the Boujave mine.

OCEANIA

Australia.—Australia continued to lead the free world in lead production although labor troubles at Mt. Isa Mines, Ltd., held production below the 459,000 tons of mine production in 1963.

The Broken Hill district, comprising mines operated by Broken Hill South, Ltd., New Broken Hill Consolidated, Ltd., North Broken Hill, Ltd., and The Zinc Corp., Ltd., produced ore at approximately the same rate as in 1963. Increase in production by Broken Hill South and North Broken Hill was offset by a decrease at New Broken Hill and The Zinc Corp. The Port Pirie smelter operated by Broken Hill Associated Smelters, Pty., Ltd., produced 230,000 tons of lead in 1964 compared with 255,000 tons in 1963. An important step in the expansion of Australian lead production was taken in November with the blowing in of what is claimed to be one of the world's largest lead blast furnaces. This furnace was expected to produce about 600 tons of lead bullion per day, nearly twice the capacity of the other furnaces at this plant. The Sulphide Corp., Pty., Ltd. operated its Imperial-type smelter at Cockle Creek, New South Wales, at improved efficiencies, and production of lead bullion was about 12 percent above the previous year.[8] Broken Hill South, Ltd., mined a slightly higher tonnage of ore and lead content was also higher at 12.9 percent in comparison to 1963. All mining was conducted in the No. 7 shaft and Browne Shaft sections with a slightly lower mill recovery due to the increasing proportion of refractory ore mined from the Browne section. Exploration and development continued but the developed ore reserve decreased by about 150,000 tons.[9] New Broken Hill Consolidated, Ltd., production of ore was slightly lower as was the lead content at 12.2 percent and the concentrates produced contained about 99,000 tons of lead Underground exploration and development lode continued and the fully outlined ore reserve developed for stoping was increased to an estimated 6 million tons containing 11 percent lead.[10] North Broken Hill, Ltd., in the fiscal year ending June 30, 1964, treated about 550,000 tons of ore, 18 percent more than in the prior year, averaging 15 percent lead and produced 98,000 tons of lead concentrates. Development was carried on in the lower levels of the mine and improvements in ore transfer and ventilation accomplished. The ore reserve at the end of the period was slightly higher and exceeded 4 million tons.[11]

The Zinc Corp., Ltd., mined and milled at a rate about 11 percent below the previous fiscal year and produced concentrates containing about 110,000 tons of lead in comparison to 131,000 tons the previous year. Mill capacity was increased some 13 percent in the last two years by improvements begun in 1962.[12]

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[7] Newmont Mining Corp. Annual Report, 1964, p. 7.
[8] The Rio Tinto Zinc Corp. Annual Report, 1964, p. 28.
[9] Broken Hill South, Ltd. Annual Report, 1964, p. 6.
[10] New Broken Hill Consolidated, Ltd. Annual Report, 1964, p. 11.
[11] North Broken Hill, Ltd. Annual Report, 1964, p. 7.

During the fiscal year ending June 30, 1964, Mount Isa Mines, Ltd. (53.7 percent owned by American Smelting and Refining Co.) produced 64,000 tons of lead. Late in August, however, labor troubles developed which resulted in loss of production and complete shutdown on December 15. Sinking of the new K57 shaft was completed and construction of the new 6,000-ton-per-day lead-zinc concentrator was well advanced at yearend. The assured silver-zinc-lead ore reserve was increased to over 30 million tons averaging 7.8 percent lead.[13]

Electrolytic Zinc Co. of Australasia, Ltd., operated the Rosebery and Hercules mines in Tasmania and mined, in the fiscal year ending June 30, 1964, a 7 percent larger tonnage averaging 5.38 percent lead from the two mines which was treated at the Rosebery concentrator to produce 17,000 tons of lead concentrate. The company, late in 1964, acquired the mining property of Farrell Mining Co., Pty., Ltd., which operated a mine about 6 miles from the Rosebery and produced about 4,500 tons of ore containing almost 15 percent lead annually.[14]

TECHNOLOGY

Increased activity in the lead industry was reflected in the expanded effort in the field of research and technology. The Lead Industries Association, Inc., announced a substantial increase in program and budget for the year and published a number of technical and semi-technical papers dealing with battery power, ceramics, roofing, vibration control, and other subjects.[15]

Lead in a new physical state with remarkable mechanical properties was reported. Dispension strengthened lead resulting from special fabricating processes was reported to have greater strength, temperature stability, and resistance to creep and fatigue than conventional metal.[16]

Storage batteries, the largest end-product use of lead, continued to receive the attention of research. The electrochemistry of batteries and operating characteristics of various combinations of electrode materials were described [17] and the structure of electrodeposits of lead reported.[18]

Research on organolead compounds has developed several new chemicals with good potential as industrial biocides.[19] A review of organolead chemistry and application was published.[20] One of the earliest materials known to be capable of current rectification and use as a semiconductor device was the lead-sulfide crystal. Research still continues on the electrical properties and use of lead alloys in semiconductors.[21]

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[12] The Rio Tinto Zinc Corp. Annual Report, 1964, p. 28.

[13] American Smelting and Refining Co. Annual Report, 1964, p. 17.

[14] Electrolytic Zinc Co. of Australasia, Ltd. Annual Report, 1964, pp. 15–17.

[15] International Lead-Zinc Research Organization (ILZRO) Digest. No. 14, October 1964, p. C–1.

[16] Roberts, D. H., and N. A. Ratcliff. Dispension Strengthened Lead in Batteries. Metallurgia (Manchester, England), v. 70, No. 421, November 1964, pp. 223–227.

[17] Osthoff, R. C. Batteries. Internat. Sci. and Technol., No. 35, November 1964, pp. 48–50, 52, 54, 57.

[18] Burbank, Jeanne. Morphology of PbO_2 in the Positive Plates of Lead Acid Cells. J. Electrochem. Soc., v. 111, No. 7, July 1964, pp. 765–768.

[19] Chemical Week. Organo-Lead Job Hunt. V. 95, No. 17, Oct. 24, 1964, pp. 95–97.

[20] Willemsens, L. C. Organolead Chemistry. International Lead-Zinc Research Organization (ILZRO), New York, 1964, p. 111.

The technology of lead smelting and refining was not neglected. An Austrian firm is reputed to have developed a new lead smelting process using pelletized lead concentrates and a rotating-hearth furnace. The design and installation of a continuous tapper for lead blast furnace was described.[22] Sulfate formation during roasting was studied and the extent of the reactions determined in the sinter bed.[23] Among the vast number of research and development projects is the use of chemical techniques in metals winning and some of these promising techniques were described.[24]

U.S. patents were granted for methods of producing basic lead carbonate,[25] hemispherical lead pellets,[26] lead oxide coatings on galvanic battery electrodes,[27] and ribbed separators for lead-acid batteries.[28] Patents were also granted for an alloy solder,[29] lead glass for optical use,[30] and for a variation in tetramethyl lead manufacture.[31]

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[21] Butler, J. F. Diffused Junction Diodes of PbSe and PbTe. J. Electrochem. Soc., v. 111, No. 10, October 1964, pp. 1150–1154.

[22] Roy, J. T., and J. T. Stone. Lead Blast Furnaces Continuously Tapped. J. Metals, v. 15, No. 11, November 1963, pp. 827–829.

[23] Tuffley, J. R., and B. Russell. Sulfate Formation During the Roasting of Lead Sulfide. Trans. AIME, v. 230 (Met. Soc.), No. 5, August 1964, pp. 950–956.

[24] Lewis, Clifford J., and James L. Drobnick. A Look at Some Promising Chemical Techniques for Metals Winning. Min. Eng., v. 15, No. 11, November 1963, pp. 43–45.

[25] Walsh, Robert J. (assigned to Monsanto Company, Inc.). Production of Basic Lead Carbonate. U.S. Pat. 3,150,927, Sept. 29, 1964.

[26] Jacklin, Clarence (assigned to Nalco Chemical Company, Chicago, Ill.). Process for Forming Hemispherical Lead Pellets. U.S. Pat. 3,150,212, Sept. 22, 1964.

[27] Darland, William G., Jr. (assigned to U.S. Department of the Navy). Galvanic Battery Electrode. U.S. Pat. 3,150,008, Sept. 22, 1964.

[28] Ashworth, John S. (assigned to The Chloride Electrical Storage Co., Ltd., London). Electric Accumulators of the Lead-Acid Type. U.S. Pat. 3,143,585, Aug. 4, 1964.

[29] Hack, Carl H., and Elbert J. Minarcik (assigned to National Lead Co., Inc., New York). Lead Base Solder Alloy. U.S. Pat. 3,147,114, Sept. 1, 1964.

[30] Faulstich, Marga (assigned to Jenaer Galswerk Schott & Gen., Mainz, West Germany). Lead Glass for Optical Use. U.S. Pat. 3,149,984, Sept. 22, 1964.

[31] Scales, Richard K. (assigned to Ethyl Corp., New York). Manufacture of Lead Compounds. U.S. Pat. 3,145,224, Aug. 18, 1964.

Lime

By William R. Barton [1] and Perry G. Cotter [2]

◆

PRODUCTION of lime by plants was a record 16.1 million tons, 11 percent more than in 1963. The total was comprised of 61 percent open-market production and 39 percent captive lime production. Lime for use in basic oxygen furnaces of the steel industry continued to be the most rapidly expanding market.

TABLE 1.—Salient lime statistics in the United States

(Thousand short tons and thousand dollars)

	1955-59 (average)	1960	1961	1962	1963	1964
Active open-market plants	150	157	220	215	208	210
Sold or used by producers:						
Quicklime	6,261	8,271	8,998	9,509	10,128	11,370
Hydrated lime	2,257	2,715	2,269	2,386	2,444	2,551
Dead-burned dolomite	2,090	1,949	1,982	1,858	1,949	2,168
Total	10,608	12,935	13,249	13,753	14,521	16,089
Value [1]	$136,659	$172,733	$177,463	$186,754	$199,389	$223,167
Average value per ton	$12.88	$13.35	$13.39	$13.58	$13.73	$13.87
Open-market	8,447	8,189	8,072	8,145	8,889	9,801
Captive	[2] 2,161	[2] 4,746	5,177	5,608	5,632	6,287
Imports for consumption	39	32	37	78	101	123
Exports	66	61	30	20	17	30

[1] Selling value, f.o.b. plant, excluding cost of containers.
[2] Incomplete figures; before 1961 the coverage of captive plants was only partial.

DOMESTIC PRODUCTION

The first complete lime operation in South Dakota began production in March. Its largest consumer was the South Dakota Highway Department, but potential markets were envisaged in Nebraska, Montana, North Dakota, and Wyoming.[3]

A plant of Chas. Pfizer & Co., Inc., went on stream August 13, at Lucerne Valley, Calif. It featured the first U.S. installation of a three-compartment fluo-radiation kiln.[4] Bethlehem Steel Co. announced plans to spend almost $10 million for lime facilities, including three calcimatic kilns, at Lackawanna, N.Y. The kilns will produce 600 tons of lime per day for consumption by two basic oxygen process furnaces.

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[1] Commodity specialist, Division of Minerals.
[2] Formerly commodity specialist, Division of Minerals (now retired).
[3] Simpson, Jack R. New Rotary-Kiln Lime Plant in South Dakota. Pit and Quarry, v. 56, No. 11, May 1964, pp. 92–97.
[4] Diehl, D. B. Three-Compartment Fluidized-Solids Kiln Maintain ± 10° F in Lime Calcining. Minerals Processing, v. 5, No. 12, December 1964, pp. 27–31.

TABLE 2.—Lime, primary, sold or used by producers in the United States, by States

State	Sold			Used			Total		
	Active plants	Short tons	Value	Active plants	Short tons	Value	Active plants	Short tons	Value
1963:									
Alabama	5	W	W	4	W	W	6	596,001	$6,974,244
Arizona	3	100,619	$1,567,771	4	80,241	$1,480,446	6	180,860	3,048,217
Arkansas	1	W	W	4	W	W	5	166,795	2,236,837
California	5	141,253	2,590,593	12	346,227	6,341,096	16	487,480	8,931,689
Colorado	2	W	W	13	W	W	15	127,643	2,103,817
Connecticut	1	35,262	666,313	----	----	----	1	35,262	666,313
Florida	2	W	W	1	W	W	3	126,430	1,995,878
Hawaii	2	W	W	1	W	W	2	12,056	427,882
Idaho	----	----	----	4	60,207	873,931	4	60,207	873,931
Louisiana	2	W	W	3	W	W	5	656,952	6,861,552
Massachusetts	3	130,126	2,218,699	1	14,763	207,000	3	144,889	2,425,699
Michigan	4	353,376	5,072,214	9	1,017,589	13,359,159	10	1,370,965	18,431,373
Mississippi	----	----	----	1	W	W	1	W	W
Missouri	5	W	W	1	W	W	5	1,239,859	14,385,950
Montana	1	8,611	152,000	5	105,547	1,137,650	6	114,158	1,289,650
Nevada	3	W	W	----	----	----	3	W	W
New Mexico	----	----	----	1	27,125	377,038	1	27,125	377,038
New York	2	W	W	2	W	W	3	W	W
Ohio	17	2,049,930	32,261,118	8	1,156,994	13,696,162	22	3,206,924	45,957,280
Oklahoma	1	W	W	----	----	----	1	W	W
Oregon	1	44,425	926,022	2	42,256	909,206	3	86,681	1,835,228
Pennsylvania	18	1,188,217	17,547,940	----	----	----	18	1,188,217	17,547,940
Tennessee	2	W	W	2	W	W	3	W	W
Texas	8	593,714	6,493,863	6	537,491	6,531,946	11	1,131,205	13,025,809
Utah	3	W	W	4	W	W	7	156,264	2,667,804
Virginia	8	W	W	1	W	W	9	638,800	8,058,415
Washington	1	W	W	2	W	W	3	W	W
West Virginia	3	W	W	1	W	W	3	W	W
Illinois, Iowa, Minnesota, Nebraska, South Dakota, Wisconsin, Wyoming	13	1,093,475	17,584,748	14	126,888	2,377,777	27	1,220,363	19,962,525
Maryland, New Jersey, Vermont	6	63,286	900,460	----	----	----	6	63,286	900,460
Undistributed	----	3,087,643	40.614,942	----	2,116,992	23,500,433	----	1,483,835	18,402,996
Total	122	8,889,000	128,596,000	106	5,632,000	70,792,000	208	14,521,000	199,389,000
Puerto Rico	1	3,549	88,725	1	552	14,054	2	4,101	102,779

1964:									
Alabama	5	W	W	4	W	W	6	599, 147	7, 118, 369
Arizona	3	W	W	3	W	W	6	176, 769	2, 920, 053
Arkansas	1	W	W	4	W	W	5	188, 522	2, 814, 479
California	5	160, 347	2, 873, 871	13	416, 521	7, 438, 112	16	576, 868	10, 311, 983
Colorado	3	W	W	13	W	W	15	138, 066	2, 193, 139
Connecticut	1	30, 413	564, 278	1	8, 161	124, 455	1	38, 574	688, 733
Florida	2	W	W	1	W	W	3	116, 841	1, 813, 617
Hawaii	2	W	W	1	W	W	2	8, 737	320, 790
Idaho	-----	-----	-----	4	W	W	4	W	
Louisiana	2	W	W	3	W	W	5	724, 553	8, 311, 972
Massachusetts	3	W	W	2	W	W	3	171, 398	2, 703, 276
Michigan	3	W	W	8	W	W	9	1, 429, 724	19, 245, 883
Mississippi	-----	-----	-----	1	W	W	1	W	W
Missouri	4	W	W	1	W	W	4	1, 218, 695	14, 327, 617
Montana	1	W	W	5	W	W	6	135, 880	1, 384, 524
Nevada	3	W	W	-----	-----	-----	3	W	W
New Mexico	-----	-----	-----	1	25, 346	352, 309	1	25, 346	352, 309
New York	1	W	W	2	W	W	2	W	W
Ohio	18	2, 364, 426	37, 665, 532	9	1, 299, 979	15, 642, 338	22	3, 664, 405	53, 307, 870
Oklahoma	1	W	W	-----	-----	-----	1	W	W
Oregon	2	W	W	2	W	W	4	95, 250	1, 917, 956
Pennsylvania	18	1, 440, 285	20, 656, 024	-----	-----	-----	18	1, 440, 285	20, 656, 024
Tennessee	2	W	W	2	W	W	3	W	W
Texas	10	634, 348	7, 559, 611	7	716, 017	9, 641, 467	13	1, 350, 365	17, 201, 078
Utah	3	W	W	4	W	W	7	163, 240	2, 917, 207
Virginia	8	W	W	1	W	W	9	780, 290	9, 780, 920
Washington	1	W	W	2	W	W	3	W	W
West Virginia	3	W	W	2	W	W	3	W	W
Illinois, Iowa, Minnesota, Nebraska, South Dakota, Wisconsin, Wyoming	15	1, 224, 836	19, 738, 281	15	109, 339	2, 024, 821	29	1, 334, 175	21, 763, 102
Maryland, New Jersey, Vermont	6	57, 292	822, 011	-----	-----	-----	6	57, 292	822, 011
Undistributed	-----	3, 889, 457	53, 510, 966	-----	3, 712, 105	44, 552, 605	-----	1, 654, 450	20, 293, 769
Total	126	9, 801, 000	143, 391, 000	111	6, 287, 000	79, 776, 000	210	16, 089, 000	223, 167, 000
Puerto Rico	1	17, 825	573, 925	-----	-----	-----	1	17, 825	573, 925

W Withheld to avoid disclosing individual company confidential data.

Texas Lime Co. began construction of a 300-ton-per-day hydrated lime plant at Cleburne, Tex. The plant will feature a fluo-solids calciner and will supplement production from three rotary kilns at an existing company facility 15 miles away. Marblehead Lime Co. announced plans to erect a 700,000-ton-per-year lime plant near River Rouge, Mich. The plant will increase availability of lime to the many new oxygen steel furnaces in the Detroit area.

Air Reduction Chemical & Carbide Co. announced plans to build a second lime-reclamation plant in Louisville, Ky. It will be built next to the company's calcium carbide and acetylene-generating facility and will have the same capacity, 330 tons per day, as the existing lime-reclamation plant that was completed in 1962. The operating unit was described in a journal article.[5] Several papers were published describing other lime conservation and reclamation facilities.[6] Lime-Reclamation (Regenerated Lime) was practiced mainly at pulpmills and to a lesser extent at calcium carbide and municipal water treatment plants.

TABLE 3.—Regenerated lime produced in the United States

State	Quicklime	
	Short tons	Value
1963:		
Alabama	323,416	$4,860,917
Arkansas	105,273	1,408,487
Florida	401,766	5,502,708
Georgia	315,291	5,865,317
Maine	32,277	459,947
North Carolina [1]	293,916	4,259,060
Ohio	89,082	1,066,979
Oregon	127,325	3,174,750
Pennsylvania	21,705	361,388
South Carolina	289,152	2,906,590
Wisconsin	26,000	453,700
Undistributed [2]	1,767,885	26,891,119
Total	3,793,000	57,211,000
1964:		
Alabama	312,410	4,290,108
Arkansas	153,421	3,146,503
California	42,531	$1,007,432
Florida	419,873	6,226,300
Georgia	335,428	6,489,272
Kentucky	217,748	2,754,500
Louisiana [3]	300,787	5,600,485
Maine	32,711	489,029
Michigan [3]	56,642	594,985
North Carolina	318,429	3,808,000
Ohio	93,001	1,113,410
Oregon	137,000	3,388,000
Pennsylvania	23,088	384,415
South Carolina	278,125	3,525,518
Tennessee	121,166	1,901,406
Virginia	83,447	1,168,258
Washington [3]	354,386	7,585,411
Wisconsin	6,683	116,618
Undistributed [2]	377,110	5,907,363
Total	3,664,000	59,497,000

[1] Includes 619 tons of hydrated lime valued at $8,760.

[2] Includes 382,625 tons of hydrated lime valued at $3,174,738 in 1963, and 71,150 tons valued at $922,499 in 1964, and other States withheld to avoid disclosing individual company confidential data.

[3] Includes hydrated lime.

A special lime issue of "Rock Products" magazine included an article on rotary kiln efficiency and practical means of attaining increased lime production while lowering fuel requirements.[7] The same issue contained articles on lime production from clam shells in Louisiana, an expansion program at a Texas lime plant, and a discussion of potential new markets for lime.

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[5] Herod, B. C. Waste Problem Whipped at Acetylene Plants. Pit and Quarry, v. 56, No. 11, May 1964, pp. 98-99, 102-105.

[6] Chemical Week. New Lime From Old. V. 94, No. 25, June 20, 1964, pp. 83-84, 86.

Fulwider, W. R. New Lime Production in the Old South. Minerals Processing, v. 5, No. 10, October 1964, pp. 28-30.

Minerals Processing. Money in the Bank. V. 5, No. 8, August 1964, pp. 12-13.

Pit and Quarry. First Fluidized Solids Lime Mud Recovery System in a Paper Mill. V. 56, No 11, May 1964, pp. 116-119, 143.

[7] Azbe, V. J. A Super Rotary Kiln. Rock Products (Special Lime Issue), v. 69, No. 7, July 1964, pp. 57-63.

TABLE 4.—Number and production domestic lime plants, by size of operation[1]

Annual production (short tons)	1963 production			1964 production		
	Plants	Thousand short tons	Percent of total	Plants	Thousand short tons	Percent of total
Less than 10,000	67	298	2	30	228	1
10,000 to less than 25,000	37	611	4	33	684	4
25,000 to less than 50,000	39	1,423	10	44	1,512	10
50,000 to less than 100,000	25	1,828	13	43	3,464	22
100,000 to less than 200,000	21	3,212	22	54	8,070	50
200,000 and over	19	7,149	49	6	2,131	13
Total[2]	208	14,521	100	210	16,089	100

[1] Includes captive tonnage.
[2] Data may not add to totals shown because of rounding.

TABLE 5.—Lime sold or used by producers in the United States, by uses

(Short tons)

Use	1963			1964		
	Open market	Captive	Total	Open market	Captive	Total
Agriculture	176,000	(1)	176,000	200,000	(1)	200,000
Construction:						
Finishing lime	463,838	----------	463,838	441,143	W	441,143
Mason's lime	457,376	----------	457,376	466,370	W	466,370
Soil stabilization	395,577	83	395,660	449,621	W	449,621
Other	39,392	78,903	118,295	19,822	W	19,822
Total[2]	1,356,000	79,000	1,435,000	1,377,000	104,000	1,481,000
Chemical and other industrial:						
Alkalies (ammonium, potassium, and sodium compounds)	11,064	3,129,125	3,140,189	13,191	3,368,705	3,381,896
Brick, sand-lime, slag, and silica	32,267	----------	32,267	42,471	----------	42,471
Calcium carbide	583,869	368,147	952,016	602,785	355,868	958,653
Glass	243,717	----------	243,717	301,534	----------	301,534
Other chemical uses[3]	632,131	838,327	1,470,458	594,977	1,039,564	1,634,541
Metallurgical uses:						
Aluminum	91,559	90,284	181,843	93,016	W	93,016
Copper smelting	107,574	178,457	286,031	122,897	207,418	330,315
Magnesium	17,814	93,539	111,353	19,183	W	19,183
Other nonferrous	4,720	----------	4,720	----------	----------	----------
Ore concentration[4]	62,226	2,840	65,066	92,897	----------	92,897
Steel flux	1,842,789	71,643	1,914,432	2,108,212	157,838	2,266,050
Miscellaneous steel processing (wire drawing, etc.)[5]	19,190	41,664	60,854	217,293	293,762	511,055
Paper and pulp	747,896	40,212	788,108	795,076	48,048	843,124
Sewage and trade-wastes treatment	202,478	43,798	246,276	186,213	14,415	200,628
Sugar	25,497	585,735	611,232	29,713	624,819	654,532
Water softening and treatment	852,672	342	853,014	909,267	337	909,604
Total[2]	5,477,000	5,484,000	10,961,000	6,129,000	6,111,000	12,239,000
Refractory lime (dead-burned dolomite)	1,880,000	69,000	1,949,000	2,096,000	72,000	2,168,000
Grand total[2]	8,889,000	5,632,000	14,521,000	9,802,000	6,287,000	16,089,000

W Withheld to avoid disclosing individual company confidential data.
[1] Included with open-market agricultural lime to avoid disclosing confidential data.
[2] Data may not add to totals shown because of rounding.
[3] Includes alcohol, calcium-carbonate (precipitated), coke and gas, food and food byproducts, insecticides, medicine and drugs, explosives, oil-well drilling, paint, petrochemicals, petroleum refining, rubber, tanning, salt, miscellaneous, and unspecified uses.
[4] Includes flotation, cyanidation, bauxite purification, and magnesia manufacture.
[5] Includes wire drawing and various metallurgical uses.

CONSUMPTION AND USES

An important paper related the properties of lime to raw materials, production process, and to end use potential.[8]

The growth rate for basic-oxygen-furnace steel was projected as increasing about fourfold from 1963 through 1967 with parallel increase in lime requirements for this process.[9] Adding to the burgeoning demand for lime for this use, some firms were reported developing pulverized quicklime as a partial substitute for dolomite in the production of self-fluxing sinters.[10] The development of lime for soil stabilization was reviewed.[11] In the United States, the area of lime stabilized construction emplaced each year has grown from almost nothing in 1953 to more than 40 million square yards in 1962. The experience gained from liming Maine soils for potato, dairy, and sweet corn farming was summarized.[12]

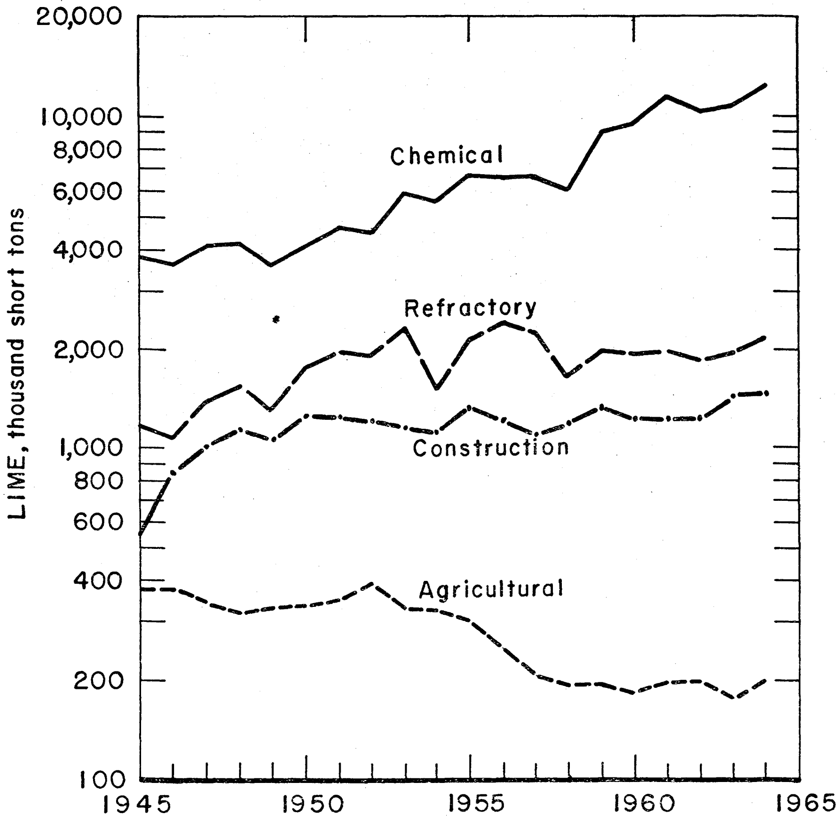

FIGURE 1.—Trends in major uses of lime.

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[8] Mayer, R. P., and R. A. Stowe. Physical Characterization of Limestone and Lime. National Lime Association, Azbe Award Paper No. 4, 1964, 26 pp.

[9] National Lime Association. Oxygen Converter Steel Growth. Limeographs, v. 31, December 1964–January 1965, p. 37.

[10] National Lime Association. Quicklime In Sinter Mixes. Limeographs, v. 30, April–May 1964, p. 59.

[11] Denman, W. K. J. The Potential of Soil Stabilization By Lime. Cement Lime and Gravel (London), v. 39, No. 6, June 1964, pp. 197–201.

[12] Hutchinson, F. E., H. J. Murphy, and D. T. Lewis. Effect of Liming. Maine Agricultural Experiment Station, Orono, Maine, Bull. 617, 1964, 39 pp.

TABLE 6.—Destination of shipments of primary open-market lime sold in the United States, by States

(Short tons)

State	1963			1964		
	Quicklime	Hydrated lime	Total	Quicklime	Hydrated lime	Total
Alabama	212,202	9,714	221,916	229,056	12,540	241,596
Alaska	-----	575	575	W	W	1,570
Arizona	W	W	93,908	W	W	93,780
Arkansas	27,038	10,790	37,828	32,601	15,207	47,808
California	222,431	110,656	333,087	222,796	137,358	360,154
Colorado	39,007	16,991	55,998	35,115	22,902	58,017
Connecticut	34,457	23,881	58,338	55,812	24,860	80,672
Delaware	35,304	10,919	46,223	37,415	11,090	48,505
District of Columbia	W	W	9,338	W	W	6,832
Florida	137,562	60,707	198,269	127,013	63,227	190,240
Georgia	76,169	19,145	95,314	73,906	19,044	92,950
Hawaii	-----	W	W	-----	W	W
Idaho	W	W	W	W	W	W
Illinois	466,234	134,315	600,549	520,769	137,948	658,717
Indiana	612,909	41,609	654,518	668,054	43,926	711,980
Iowa	W	W	90,871	W	W	80,458
Kansas	42,568	17,220	59,788	35,072	23,538	58,610
Kentucky	W	W	433,385	457,819	17,534	475,353
Louisiana	107,378	58,856	166,234	131,994	45,360	177,354
Maine	48,793	10,474	59,267	43,162	10,723	53,885
Maryland	195,657	22,746	218,403	211,636	19,684	231,320
Massachusetts	21,740	48,221	69,961	W	W	40,122
Michigan	530,012	58,293	588,305	663,124	59,242	722,366
Minnesota	97,220	21,900	119,120	104,376	19,888	124,264
Mississippi	61,444	10,852	72,296	56,405	9,873	66,278
Missouri	W	W	176,019	W	W	166,412
Montana	W	W	17,020	8,759	4,233	12,992
Nebraska	W	W	20,952	W	W	23,742
Nevada	W	W	30,591	W	W	32,933
New Hampshire	W	W	7,620	W	W	10,400
New Jersey	40,765	94,505	135,270	46,066	80,893	126,959
New Mexico	W	W	18,017	W	W	20,366
New York	127,963	133,735	261,698	155,447	143,351	298,798
North Carolina	15,080	23,701	38,781	34,649	30,661	65,310
North Dakota	26,825	11,108	37,933	W	W	16,759
Ohio	857,590	141,226	998,816	1,026,257	132,635	1,158,892
Oklahoma	W	W	66,139	W	W	82,825
Oregon	47,223	16,391	63,614	49,453	16,415	65,868
Pennsylvania	1,050,898	189,696	1,240,594	1,388,100	197,409	1,585,509
Rhode Island	7,814	7,781	15,595	W	W	15,499
South Carolina	18,766	6,914	25,680	21,839	8,585	30,424
South Dakota	9,960	8,418	18,378	11,483	25,569	37,052
Tennessee	39,750	39,968	79,718	49,417	30,807	80,224
Texas	295,180	384,155	679,335	290,970	388,750	679,720
Utah	W	W	64,302	W	W	67,916
Vermont	W	W	1,786	W	W	1,238
Virginia	81,864	42,298	124,162	104,180	43,774	147,954
Washington	53,024	15,757	68,781	57,739	15,456	73,195
West Virginia	112,790	14,109	126,899	113,513	14,147	127,660
Wisconsin	83,876	61,081	144,957	82,816	67,233	150,049
Wyoming	W	W	4,738	W	W	3,820
Undistributed	837,262	214,935	17,511	429,221	249,626	14,175
Total	[1] 6,675,000	2,094,000	8,768,000	7,576,000	2,143,000	9,720,000

W Withheld to avoid disclosing individual company confidential data.

[1] Data may not add to totals shown because of rounding.

PRICES

Quotations in Engineering News-Record for delivered hydrated finishing lime in December ranged from $52.00 per ton in Seattle to $29.20 per ton in Cincinnati. The average price reported for 20 major cities was $38.94 per ton. Prices for pulverized quicklime ranged from $56.00 per ton in Boston to $26.00 per ton in Dallas, and averaged $38.15 per ton for 13 cities. The average delivered price for common hydrated lime, as reported from 20 selected cities, was $32.68 per ton.

The average value of lime sold or used by producers, f.o.b. plant, excluding the cost of containers, was $13.87 per ton compared with that of 13.73 in 1963.

FOREIGN TRADE

Imports from Canada represented 76 percent of the combined import total for all types of lime.

In 1964, Canada was the destination of 64 percent of U.S. lime exports, and Mexico received 20 percent.

TABLE 7.—U.S. imports for consumption of lime

Year	Hydrated lime		Other lime		Dead-burned dolomite [1]		Total	
	Short tons [2]	Value	Short tons [2]	Value	Short tons [2]	Value	Short tons [2]	Value
1955–59 (average)	778	$12,978	29,273	$511,350	8,319	$520,477	38,370	$1,044,805
1960	676	14,597	18,445	369,051	12,932	550,365	32,053	934,013
1961	950	21,710	31,418	491,352	4,256	233,271	36,624	746,333
1962	1,141	18,755	71,970	939,226	4,456	244,788	77,567	1,202,769
1963	692	12,226	90,676	1,004,920	9,389	454,721	100,757	1,471,867
1964	843	10,475	93,420	1,112,129	28,876	1,165,306	123,139	2,287,910

[1] Dead-burned basic refractory material consisting chiefly of magnesia and lime.
[2] Includes weight of immediate container.

Source: Bureau of the Census.

TABLE 8.—U.S. exports of lime

Year	Short tons	Value	Year	Short tons	Value
1955–59 (average)	65,803	$1,277,277	1962	19,512	$660,408
1960	61,056	991,769	1963	17,463	565,299
1961	29,969	920,668	1964	29,858	777,359

Source: Bureau of the Census.

WORLD REVIEW

Canada.—A new lime plant at Joliette, Quebec, featured a rotary kiln of 180-ton-per-day capacity and a grate-rotary kiln of 325-ton-per-day capacity. These facilities replaced an old plant consisting of 20 vertical kilns.[13]

Japan.—The Onoda Cement Co., Ltd., has developed a process using quicklime instead of limestone in the raw feed of a cement kiln.[14] Advantages claimed for the process are improved cement quality and lower labor and fuel costs.

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[13] Trauffer, W. E. Domtar Chemicals' New Joliette Plant Combines Capacity, Efficiency, and Economy. Pit and Quarry, v. 57, No. 5, November 1964, pp. 92–96, 139–142.

[14] National Lime Association. Quicklime for Cement. Limeographs, v. 31, November 1964, p. 29.

TABLE 9.—World production of quicklime, hydrated lime, and dead-burned dolomite, sold or used

(Thousand short tons)

Country [1]	1962	1963	1964 [p]
North America:			
Canada	1,424	1,451	1,491
Costa Rica [e]	4	6	7
Nicaragua	29	[e] 31	29
Puerto Rico	1	4	18
United States (sold or used by producers)	13,753	14,521	16,089
West Indies:			
Bahamas	2	3	NA
Dominican Republic	8	----	----
Haiti [e]	180	180	180
South America:			
Brazil	1,308	1,332	NA
Colombia	94	107	NA
Paraguay	16	14	20
Peru	88	94	102
Uruguay [e]	36	33	NA
Venezuela	49	53	[e] 77
Europe:			
Austria	740	759	802
Belgium	2,245	2,227	2,533
Bulgaria	766	830	913
Czechoslovakia	2,611	2,485	2,587
Denmark	162	167	176
Finland	246	229	265
France	3,078	2,919	3,056
Germany:			
East	3,686	3,811	[e] 3,900
West	10,690	10,775	11,921
Hungary	685	685	807
Ireland	183	39	47
Malta	39	18	NA
Norway	NA	NA	121
Poland	2,186	2,209	2,326
Rumania	746	806	[e] 830
Spain	203	234	NA
Sweden	798	949	NA
Switzerland	212	203	221
U.S.S.R.	18,237	17,651	[e] 19,300
Yugoslavia	847	947	999
Asia:			
Cyprus	50	65	NA
Japan	1,291	1,527	1,798
Kuwait	----	----	13
Lebanon	[e] 10	39	29
Mongolia [e]	23	28	33
Philippines	[e] 47	35	86
Ryukyu Islands	1	[e] 1	NA
Saudi Arabia	NA	7	NA
Taiwan	83	88	101
Africa:			
Cape Verde Islands	(2)	(2)	NA
Ethiopia (including Eritrea) [3]	6	5	[e] 7
Kenya	NA	NA	4
Libya [e]	19	NA	NA
South Africa, Republic of (sales)	726	719	771
South-West Africa	3	3	4
Tanzania (sales and exports)	3	1	2
Tunisia	142	164	193
Uganda	18	12	NA
Oceania:			
Australia [4]	139	NA	NA
Fiji Islands	3	6	4

[e] Estimate. [p] Preliminary. NA Data not available.

[1] Lime is also produced in Algeria, Argentina, Barbados, Burundi, Chile, China, Republic of the Congo (Leopoldville), Ecuador, Greece, Guatemala, Honduras, India, Indonesia, Iran, Israel, Italy Republic of Korea, Mexico, Morocco, Mozambique, New Zealand, Pakistan, Rhodesia (formerly Southern), Rwanda, Syrian Arab Republic, United Kingdom, and Viet-Nam, but production data are not available. In addition Bermuda, El Salvador, Guadeloupe, Netherlands Antilles, Sarawak and St. Thomas and Principe Islands produce less than 1,000 tons.

[2] Negligible.

[3] Year ended September 10 of year stated.

[4] Year ended June 30 of year stated.

Netherlands.—The Koninklyke Nederlandsche Hoogovens en Staalfabrieken N.V. plant at Ijmuiden recovers iron flue dust from basic oxygen converters in a spray cooler. It is autoclaved, blended with pulverized quicklime, and then sintered with conventional iron ore.

Puerto Rico.—The Puerto Rican Cement Co., Inc., lime plant at Ponce was described in a publication.[15] This first modern Puerto Rican lime plant opened in 1963 and marked an important step in the economic development of the island.

United Kingdom.—A new oil-fired vertical shaft lime kiln design features flash vaporization of the fuel.[16]

TECHNOLOGY

The general aspects of lime burning by the use of oil and natural gas were discussed from the viewpoint of chemical engineering, kiln design, and kiln efficiencies.[17]

A gasifier, burning the cheapest available grade of fuel oil, in a vertical kiln, produced lime which showed 96 to 98 percent conversion of $CaCO_3$ to CaO. Although the fuel oil contained 3.8 percent sulfur, the sulfur content of the lime averaged only 0.22 percent, and the lime was acceptable to the majority of steel makers.[18]

The fluidization techniques, used by the European lime industry for drying and calcining were described.[19]

Among the advantages claimed for vertical lime-burning kilns were simplicity of construction, low first cost, high thermal efficiency, and minimum decrepitation of stone.[20]

Improved plasticity and sand-carrying ability was given to hydrated lime by the addition of at least one water-soluble substance chosen from the group consisting of a lower molecular weight aliphatic alcohols, glycerol, and resin alcohol.[21]

The results of a study of the problems involved in the preparation of hydrated lime for manufacture of calcium hypochlorite were reported.[22]

To prepare a finely dispersed, silica acid-containing calcium carbonate, carbon dioxide was reacted with hydrated lime to which had been added an aqueous solution of an alkali metal silicate.[23]

In the manufacture of sand-lime mortar, lumps of calcitic lime were ball milled to minus 30 mesh, the ground lime admixed with sand, and the mixture slaked in a rotating vessel in an atmosphere of steam.[24]

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[15] Stelling, R., and B. Sonesson. Puerto Rico's First Modern Lime Plant Features Novel Kiln-Feed System. Pit and Quarry, v. 56, No. 12, June 1964, pp. 126–132.

[16] Middlemas, J. W. New Approach Developed for Lime Kiln Firing. Rock Products, v. 67, No. 11, November 1964, pp. 88–89, 108.

[17] Middlemas, J. W. Recent Developments in Lime Burning. Cement, Lime and Gravel (London), v. 39, No. 5, May 1964, pp. 151–156.

[18] Cement, Lime and Gravel (London). Lime Manufacture using an Oil-Fired Kiln. V. 39, No. 2, February 1964, pp. 53–58.

[19] Ironman, Ralph. Fluidization. Rock Products Mining and Processing, v. 67, No. 3, March 1964, pp. 95–96, 98, 100.

[20] Persons, M. F. A New Approach to the Vertical Shaft Kiln. Pit and Quarry, v. 57, No. 2, August 1964, pp. 124–129.

[21] Dunton, H. J., and James Ivan Hall (assigned to Kaiser Aluminum & Chemical Corp., Oakland, Calif.). U.S. Pat. 3,120,444, Feb. 4, 1964.

[22] Miller, T. C. Improving Calcium Hydroxide for Better Calcium Hypochlorite Production. National Lime Association, Azbe Award No. 4, 1964, p. 77.

[23] Podschus, E. (assigned to Farbenfabriken Bayer A. G., Leverhusen, West Germany). U.S. Pat. 3,133,884, May 19, 1964.

[24] McCarthy, J. E. O., and J. P. O. McCarty (assigned to M. McCarthy & Sons, Ltd.). British Pat. 952,362, Mar. 18, 1964.

Lithium

By Donald E. Eilertsen [1]

⁂

OUTPUT of domestic lithium mineral source materials was much larger in 1964 than in 1963. Imports of lithium minerals were apparently larger than in 1963.

DOMESTIC PRODUCTION

A sharp increase in output of spodumene flotation concentrate, a slight increase in output of crude dilithium sodium phosphate, and a sharp decline in output of amblygonite occurred in 1964 as compared with 1963. In addition to these materials, some lepidolite was produced and stocked.

Foote Mineral Co. mined spodumene ore from pegmatite deposits and produced spodumene flotation concentrate at Kings Mountain, N.C.; American Potash & Chemical Corp. recovered crude dilithium-sodium phosphate from Searles Lake brines at Trona, Calif.; Hough and Judson produced some hand-sorted amblygonite from the Hugo Lode mine, Keystone, S. Dak.; and Keystone Chemical Corp. produced, sold, and stocked some hand-sorted amblygonite and produced and stocked some hand-sorted lepidolite from the Ingersoll mine, Keystone, S. Dak. Production data are not disclosed as they are company confidential.

The principal consumers of lithium source materials and producers of lithium primary products were Foote Mineral Co., at Sunbright, Va., and Exton, Pa.; Lithium Corporation of America, at Bessemer City, N.C.; and American Potash & Chemical Corp., at Trona, Calif. No production figures were available for publication.

Foote Mineral Co. made a long term agreement with Metallgesellschaft AG, Frankfurt, West Germany, to sell to the German company several million tons of spodumene flotation concentrate and to exchange technological information on lithium. Foote Mineral Co. also acquired some mineral leases in the Clayton Valley area in western Nevada containing brine and began studies on recovering postassium, magnesium, sodium, lithium, and other elements from the brine.[2]

Lithium Corporation of America announced the continuation of its research on the commercial extraction and purification of lithium, potash, and sodium sulfate from brine on its 43,000 acres of land adjoining Great Salt Lake, Utah. The right to extract and sell magnesium products from the brine was sought.

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[1] Commodity specialist, Division of Minerals.

[2] Chemical Week. V. 95, No. 13, Sept. 26, 1964, p. 46.

CONSUMPTION AND USES

Data on consumption of domestic lithium minerals are withheld to avoid disclosing company confidential information. Figures on the consumption of lithium metal, alloys, and compounds were not available for publication.

Domestic and imported lithium mineral concentrates were used in the production of lithium metal, alloys, and compounds, and ceramics but mostly in the production of compounds.

Lithium compounds were used in greases for automobiles, aircraft, and industry; alkaline storage batteries; bleaches; air conditioning as dehumidifier and refrigerant; welding and brazing fluxes; ceramics and glass; neutron shield; supplying oxygen; and reactions with water to produce hydrogen for inflating rafts and other equipment.

Lithium metal was used to reduce cesium halides to cesium metal, and as material for refining various metals, alloying, and catalysis.

A new lightweight lithium-magnesium alloy attracted attention; the alloy was used to fabricate a structure for the guidance computer of the Saturn V moon rocket. Lithium doped germanium diodes became available for use in gamma ray spectroscopy.

In ceramics, lithium minerals had uses in glass, porcelain enamel ground coats, ceramic body glazes, fluxes, and low-expansion heat-resistant bodies.

PRICES

Lithium metal, 99.5-percent pure, was quoted at $9 to $11 per pound throughout 1964.[3] Prices for various lithium compounds are shown in table 1.

FOREIGN TRADE

Imports of lithium minerals for consumption are shown in table 2. Other imports for consumption were: Lithium compounds–1,264,000 pounds valued at $564,260 from Canada, 4 pounds valued at $1,937 from United Kingdom, and 27 pounds valued at $487 from West Germany; and lithium stearate–4,398 pounds valued at $997 from the Netherlands. No lithium metal and lithium salts were imported for consumption. Export figures for lithium metal, salts, and compounds were not available.

WORLD REVIEW

Brazil.—The São João del Rei district of Minas Gerais contains two generations of pegmatites; a pretectonic group of pegmatites contain accessory cassiterite, columbite, and microlite, whereas a posttectonic group of pegmatites contain accessory cassiterite, tantalite, microlite, and abundant spodumene.[4]

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[3] E&MJ Metal & Mineral Markets. V. 35, Nos. 1–52, January–December 1964.

[4] Heinrich, E. Wm. Tin-Tantalum-Lithium Pegmatites of the São João del Rei District, Minas Gerais, Brazil. Econ. Geol., v. 59, No. 6, September–October 1964, pp. 982–1002.

TABLE 1.—Prices of selected lithium compounds, in 1964

(Per pound)

Compound	January	December
Lithium aluminum hydride, lump, drums, works	$33. 00–$39. 00	$33. 00–$39. 00
Lithium carbonate:		
Drums, ton lots [1]	. 61	. 58
Technical, drums, ton lots [1]	. 55	. 50
Lithium chloride:		
Chemically pure, anhydrous, drums, ton lots	1. 235	1. 235
Technical, anhydrous, drums, carlots, truckloads, delivered or works, freight allowed	. 87	. 87
Technical, anhydrous, drums, less than carlots, freight allowed	. 88–. 92	. 88–. 92
Lithium fluoride:		
Barrels, ton lots and more, delivered	1. 55	1. 55
Barrels, less ton lots, delivered	1. 65	1. 65
Lithium hydride, powder, drums, 500-pound lots or more, works	9. 50	9. 50
Lithium hydroxide:		
Monohydrate, drums, carlots, truckloads, freight allowed [1]	. 58	. 54
Monohydrate, drums, less than carlots, freight allowed [1]	. 60	. 58
Lithium manganite drums, works	1. 35–1. 45	1. 35–1. 45
Lithium nitrate, technical, drums, 100-pounds lots	1. 15–1. 25	1. 15–1. 25
Lithium silicate, drums, works	1. 25–1. 50	1. 25–1. 50
Lithium stearate:		
Drums, carlots, works	. 475	. 475
Drums, ton lots, works	. 485	. 485
Drums, less than ton lots, works	. 535	. 535
Lithium sulfate, drums, 100-pound lots	1. 15–1. 25	1. 15–1. 50
Lithium titanate, drums, works	1. 50–2. 00	1. 50-2. 02

[1] Price changed Feb. 17.

Source: Oil, Paint and Drug Reporter.

TABLE 2.—U.S. imports for consumption of lithium minerals, by countries and U.S. customs districts

Country and U.S. customs district	1963		1964 [1]	
	Short tons	Value	Short tons	Value
Africa:				
British East Africa: South Carolina	1, 127	$31, 014		
Mozambique: South Carolina	2, 248	62, 049		
Zambia, Southern Rhodesia, and Malawi:				
Maryland	17, 967	539, 997	13, 508	$380, 449
South Carolina	1, 121	30, 831		
Total	19, 088	570, 828	13, 508	380, 449
Grand total	22, 463	663, 891	13, 508	380, 449

[1] In addition, 13,510 short tons valued at $471,312 classified as mineral substances, n.s.p.f. were believed to be lithium minerals.

Source: Bureau of the Census.

Southern Rhodesia.—Early in 1964, Bikita Minerals Ltd., was reported to be quarrying 30,000 tons of ore and recovering 5,500 tons of exportable lithium mineral concentrates monthly. The monthly rate in 1963 was 4,000 tons of lithium mineral concentrates. The upsurge in output was due to the increased demand for lithium minerals in the United States, Europe, and Japan.

United Kingdom.—Associated Lead Manufacturers, this country's only producer of lithium metal, was reported to have doubled its capacity for producing lithium metal. Technological improvements were made to its electrolytic process in use since 1960. Prior to these

TABLE 3.—Free-world production of lithium minerals, by countries[1]

(Short tons)

Country	Mineral produced	1960	1961	1962	1963	1964
North America:[2] Canada	Spodumene (Li_2O content)	103	268	250	322	525
South America:						
Argentina	Lithium minerals	153	443	496	1,285	NA
Brazil	Spodumene (exports)			165	28	NA
	Amblygonite (exports)	55				
Surinam	Amblygonite (exports)		475	827	568	NA
Europe: Spain	Amblygonite	29	19			
Africa:						
Mozambique	Lepidolite		170	302	115	NA
Rwanda	Amblygonite	2,569	1,854	359	406	325
South Africa, Republic of	Lithium minerals	173	260	1,263	417	[e] 210
Southern Rhodesia	Eucryptite	1,334	1,879	866	1,164	806
	Amblygonite		86	35	52	
	Lepidolite	15,485	24,037	21,244	16,157	22,943
	Petalite	63,335	27,698	21,704	29,946	36,449
	Spodumene	7,690	1,627	1,496	2,235	6,965
South-West Africa	Amblygonite	161	136	141	128	[e] 20
	Lepidolite	972	1,418	1,781	86	[e] 440
	Petalite	3,909	2,540	1,008	865	[e] 1,000
Uganda	Amblygonite		25	22	53	NA
Oceania: Australia	Petalite	1	108	94	437	[e] 550
	Amblygonite	17	26	31	22	
	Spodumene		6	26	24	

[e] Estimate. NA Not available.

[1] This table incorporates some revisions.

[2] U.S. figure withheld to avoid disclosing individual company confidential data.

TABLE 4.—South-West Africa: Exports of lithium mineral concentrates, by countries

Year and destination	Amblygonite		Lepidolite		Petalite	
	Short tons	Value[1]	Short tons	Value[1]	Short tons	Value[1]
1963:						
Germany, West	197	$11,772	315	$7,134	5	$120
Japan					172	4,130
United Kingdom					586	12,832
Total	197	11,772	315	7,134	763	17,082
1964:[2]						
Japan					271	6,728
Netherlands			330	7,650	323	8,035
United Kingdom			86	1,725	176	3,600
Total			416	9,375	770	18,363

[1] Converted to U.S. currency at the rate of 1 rand equals US$1.3948 (1963) and US$1.3909 (1964).

[2] January to June, inclusive.

improvements, the plant capacity was only large enough to meet this country's demand for lithium metal.[5]

TECHNOLOGY

Lithium and beryllium minerals occur together in volcanic tuff at Spor Mountain and 20 miles westward at Honeycomb Hills, Juab County, Utah; 18 samples from a deposit at Spor Mountain averaged 0.22 percent lithia, and 14 samples from a deposit at Honeycomb Hills averaged 0.09 percent lithia.[6]

Firing shrinkages, moduli of rupture, linear thermal expansion coefficients, and some X-ray diffraction data were determined for various compositions of spodumene and kaolin and compositions of petalite and kaolin.[7]

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[5] Engineering and Mining Journal. British Firm Doubles Its Lithium Metal Capacity. V. 165, No. 4, April 1964, pp. 170–172.

[6] Shawe, Daniel R., and Walter Duke. Lithium Associated With Beryllium in Ryolitic Tuff at Spor Mountain, Western Juab County, Utah. Geological Survey Research 1964, Prof. Paper 501–C, pp. C86–C87.

Procedures were developed for processing lithium fluoride powder into dense and high strength shapes for gamma-ray-free neutron shielding.[8]

Research sponsored by the Atomic Energy Commission on lithium metal of mass numbers 6 and 7 [an atom of lithium-6, ($_3Li^6$), contains 3 electrons outside its nucleus and 3 protons plus 3 neutrons inside it; an atom of lithium-7, ($_3Li^7$), has an additional neutron in the nucleus as well] found that crystalline Li–6 has a lattice spacing slightly greater than Li-7. The slight difference was enough to establish the quantum-mechanical prediction that atoms of a lattice vibrate even at absolute zero temperature. Knowledge of the atomic spacing and the mass of the individual atoms permitted calculation of the density as 0.46 gram per cubic centimeter. Consequently, Li–6 is the lightest metal in the world, and very likely in the universe under standard conditions.

Numerous patents were issued on lithium recovery,[9] lithium compounds preparation,[10] and lithium compositions.[11]

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[7] Fishwick, J. H., R. R. Van Der Beck, and R. W. Talley. Low Thermal Expansion Compositions in the Systems Spodumene-Kaolin and Petalite-Kaolin. Am. Ceram. Soc. Bull., v. 43, No. 11, November 1964, pp. 832–835.

[8] Svikis, V. D. Dense Lithium Fluoride for Gamma-Ray-Free Neutron Shielding. Canada Dept. Mines and Tech. Surveys, Research Rept. R 119, February 1964, 30 pp.

[9] Archambault, Maurice (assigned to Ministere des Richesses Naturelles, Province de Quebec, Canada). Process for Producing Lithium Carbonate With Concomitant Recovery of Reactants. U.S. Pat. 3,131,022, Apr. 28, 1964.

Goodenough, Robert D., and Thomas G. Cook (assigned to The Dow Chemical Co., Midland, Mich.). Lithium Fluoride Production. U.S. Pat. 3,132,922, May 12, 1964.

King, William R. (assigned to Kaiser Aluminum & Chemical Corp., Oakland, Calif.). Method of Recovering Lithium Values. U.S. Pat. 3,151,934, Oct. 6, 1964.

[10] Bach, Ricardo O. (assigned to Lithium Corporation of America, Inc., New York). Preparation of Lithium Peroxide. U.S. Pat. 3,134,646, May 26, 1964.

Bach, Ricardo O., and William W. Boardman, Jr. (assigned to Lithium Corporation of America, Inc., New York). Process for Producing Anhydrous Lithium Peroxide by the Use of a Substantially Water-Immiscible Organic Liquid. U.S. Pat. 3,147,075, Sept. 1, 1964.

Beumel, Jr., Oscar F. (assigned to Foote Mineral Co., Philadelphia, Pa.). Method of Making Organolithium Compounds. U.S. Pat. 3,155,736, Nov. 3, 1964.

Bragdon, Robert W., and Frank P. Del Guidice (assigned to Metal Hydrides, Inc., Beverly, Mass.). Method for Preparing Lithium Borohydride. U.S. Pat. 3,151,930, Oct. 6, 1964.

Bragdon, Robert W., and Frank P. Del Guidice (assigned to Metal Hydrides, Inc., Beverly, Mass.). Preparation of Lithium Aluminum Hydride. U.S. Pat. 3,162,508, Dec. 22, 1964.

Eberly, Kenneth C. (assigned to The Firestone Tire & Rubber Co., Akron, Ohio). Preparation of Alkyllithium Compounds. U.S. Pat. 3,122,592, Feb. 25, 1964.

Groves, Kenneth O. (assigned to The Dow Chemical Co., Midland, Mich.). Preparation of Lithium Perchlorate-Hydrazine Coordination Compound. U.S. Pat. 3,146,062, Aug. 25, 1964.

Heying, Theodore L. (assigned to Olin Mathieson Chemical Corp., Virginia). Lithium Decarborane Tetrahydrofuran Adduct. U.S. Pat. 3,134,789, May 26, 1964.

Porter, Lee M. (assigned to Shell Oil Co., Delaware). Process for Preparing Block Copolymers Utilizing Organolithium Catalysts. U.S. Pat. 3,149,182, Sept. 15, 1964.

[11] Arthur, Edwin P., and John E. Leonard (assigned to Beckman Instruments, Inc., California). Lithia-Alumina-Silica Glass Containing Phosphorus. U.S. Pat. 3,143,488, Aug. 4, 1964.

Gilman, Lucius G. (assigned to Monsanto Research Corp., St. Louis, Mo.). Solid Solutions of Lithium Perchlorate in Polymer. U.S. Pat. 3,148,097, Sept. 8, 1964.

Greenwood, John, and Ernest A. Saxon-Napier (assigned to Esso Research and Engineering Co., Delaware). Lithium Greases. U.S. Pat. 3,158,574, Nov. 24, 1964.

Haden, Walter L., Jr., and Frank J. Dzierzanowski (assigned to Minerals & Chemicals Philipp Corporation, Menlo Park, N.J.). Synthetic Crystalline Lithium Aluminum Silicate Zeolite and Method for Making Same. U.S. Pat. 3,123,441, Mar. 3, 1964.

Hedrick, Ross M., Edward H. Mottus, and Lucius Gilman (assigned to Monsanto Chemical Co., St. Louis, Mo.). Solid Propellant Containing Lithium Perchlorate. U.S. Pat. 3,117,898, Jan. 14, 1964.

Hegyi, Imre J. (assigned to Radio Corporation of America, Inc., Delaware). Lithium-Manganese Ferromagnetic Ferrite Core. U.S. Pat. 3,146,205, Aug. 25, 1964.

Saia, Anthony (assigned to U.S. Government). High Strength Magnesium-Lithium Base Alloys. U.S. Pat. 3,119,689, Jan. 28, 1964.

Scott, William P. (assigned to Continental Oil Co., Ponca City, Okla.). Extreme Pressure Lubricants. U.S. Pat. 3,133,020, May 12, 1964.

Slack, Ronald, and Kenneth R. H. Wooldridge (assigned to May & Baker, Ltd., Essex, England). Isothiazol-5-YL Lithium Derivatives. U.S. Pat. 3,145,214, Aug. 18, 1964.

Magnesium

By Lloyd R. Williams [1]

◆

THE UPWARD trend in use of magnesium continued and was stimulated by lower price offers under certain circumstances by the principal producer. In addition at least three companies were considered installing primary magnesium production plants in the United States. The domestic output of primary metal approached 80,000 tons, the largest quantity since 1953, and despite this supply there was a ready market for 4,350 tons of surplus metal from the national stockpile.

A compilation of papers presented at the World Magnesium Congress at Montreal, Canada, in October 1963 included industry reviews for 8 major producing countries and 22 technical reports.[2]

TABLE 1.—Salient magnesium statistics

(Short tons)

	1955-59 (average)	1960	1961	1962	1963	1964
United States:						
Production:						
Primary magnesium	54,375	40,070	40,745	68,955	75,845	79,488
Secondary magnesium	10,046	10,348	8,125	9,610	[r] 9,225	11,790
Shipments: Primary	50,538	54,350	55,515	69,410	72,255	74,580
Imports for consumption	917	401	1,005	2,359	[r] 1,850	2,227
Exports	2,929	4,467	6,160	6,426	[r] 15,484	15,949
Consumption	44,284	37,100	45,533	47,320	51,240	54,748
Price per pound—cents	33.83	35.25	35.25	35.25	35.25	35.25
World: Primary production	102,000	102,500	116,800	147,300	160,000	165,900

[r] Revised figure.

LEGISLATION AND GOVERNMENT PROGRAMS

In February 1964 a revised national stockpile objective of 145,000 tons was established for magnesium by the Office of Emergency Planning. The previous objective, set in 1959, had been 107,000 tons. At yearend the stockpile contained 171,383 tons or 118 percent of the new objective.

An additional 4,350 tons of magnesium ingots was sold from the stockpile bringing the total sold to 7,800 tons since disposal of 12,500 tons was authorized in March 1962. Another 235 tons was utilized by a government agency in 1962. During 1964 offers to sell 700-ton lots from the stockpile were made about every 60 days on a sealed bid basis.

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[1] Commodity specialist, Division of Minerals.

[2] Mangnesium Association. 20th Anniversary Proceedings, World Magnesium Congress, Montreal, Canada, Oct. 15–17, 1963. Detroit, Mich., 1963. 134 pp.

DOMESTIC PRODUCTION

Production of 80,000 tons of primary magnesium in the United States was 5 percent more than in 1963. Alabama Metallurgical Corp. produced magnesium metal at Selma, Ala.; Chas. Pfizer & Co., Inc., obtained ownership of the former Government-owned plant at Canaan, Conn., for $892,000 and continued supplying magnesium to the Atomic Energy Commission; The Dow Chemical Co. operated plants at Freeport and Velasco, Tex., and planned to increase capacity to 100,000 tons. Titanium Metals Corp. of America, Henderson, Nev., a subsidiary of National Lead Co., recovered and recycled magnesium for use in titanium production. The parent company, in conjunction with H-K Co. of Salt Lake City, Utah, planned to produce magnesium metal in a prototype eletrolytic unit at Henderson from magnesium chloride recovered from Great Salt Lake. Kaiser Aluminum & Chemical Corp. acquired the assets of Standard Magnesium & Chemical Co. and planned to build a primary magnesium production plant. Standard Magnesium had been the largest U.S. secondary producer and had extrusion and fabricating facilities. The new organization became the Standard Magnesium Division of the Kaiser organization. Harvey Aluminum, Inc., had announced in 1963 plans to build a 20,000-ton primary magnesium plant in the Pacific Northwest, but no further developments were reported in 1964.

TABLE 2.—Magnesium recovered from scrap processed in the United States, by kinds of scrap and forms of recovery

(Short tons)

	1955–59 (average)	1960	1961	1962	1963[r]	1964
Kind of scrap:						
New scrap:						
Magnesium-base	3, 105	3, 179	1, 905	4, 700	4, 183	4, 505
Aluminum-base	2, 009	2, 825	1, 500	1, 770	2, 848	3, 177
Total	5, 114	6, 004	3, 405	6, 470	7, 031	7, 682
Old scrap:						
Magnesium-base	4, 246	3, 560	4, 260	2, 620	1, 150	2, 998
Aluminum-base	686	784	460	520	1, 044	1, 110
Total	4, 932	4, 344	4, 720	3, 140	2, 194	4, 108
Grand total	10, 046	10, 348	8, 125	9, 610	9, 225	11, 790
Form of recovery:						
Magnesium alloy ingot[1]	3, 694	3, 828	1, 090	1, 110	2, 227	2, 875
Magnesium alloy castings (gross weight)	167	103	360	650	404	37
Magnesium alloy shapes	3	3	350	195	75	50
Aluminum alloys	3, 151	3, 208	1, 910	1, 850	3, 839	4, 468
Zinc and other alloys	41	54	1, 095	560	435	23
Chemical and other dissipative uses	139	255	1, 350	260	754	588
Cathodic protection	2, 851	2, 897	1, 970	4, 985	1, 491	3, 749
Total	10, 046	10, 348	8, 125	9, 610	9, 225	11, 790

[r] Revised.

[1] Figures include secondary magnesium content of both secondary and primary magnesium alloy ingot.

CONSUMPTION AND USES

Magnesium was used for platform trucks, lawn mower housings, and masonry tools. The weight of a new hydroplane was said to have been reduced 33 percent below that of its predecessor by using magnesium for structural members, gas tank, and skin. The hull was constructed of thin magnesium skin bonded to 5-ply plywood.

Because of its low neutron absorption, magnesium is a useful structural material in nuclear reactors. Casting methods used by the United Kingdom Atomic Energy Authority for making reactor components were described.[3] Alloys containing 0.75 percent manganese or 0.6 percent zirconium were used. Special purity alloys are required to assure the components do not become radioactive in use.

TABLE 3.—Consumption of primary magnesium (ingot equivalent and magnesium content of magnesium-base alloys), in the United States by uses

(Short tons)

Use	1955–59 (average)	1960	1961	1962	1963	1964
For structural products:						
Castings:						
Sand	5,979	2,561	2,408	3,464	3,280	2,229
Die [1]	1,894	[1] 1,528	[1] 1,328	3,660	5,580	4,757
Permanent mold	870	745	464	901	1,400	732
Wrought products:						
Sheet and plate	5,405	4,112	4,434	6,352	5,650	4,897
Extrusions (structural shapes, tubing)	4,222	2,580	3,990	6,240	3,370	4,419
Forgings	568	893	767	415	220	293
Total	18,938	12,419	13,391	21,032	19,500	17,327
For distributive or sacrificial purposes:						
Powder	559	430	244	465	1,175	(2)
Aluminum alloys	12,238	12,511	19,754	18,405	21,780	21,880
Zinc alloys	(3)	(3)	27	100	70	99
Other alloys	467	421	1,017	896	1,420	1,705
Scavenger and deoxidizer	677	788	344	1,120	150	141
Chemical	202	276	297	430	470	2,684
Cathodic protection (anodes)	3,001	3,264	2,406	2,024	2,985	4,983
Reducing agent for titanium, zirconium, hafnium, and beryllium [4]	8,036	6,978	7,950	2,843	3,070	3,764
Other [5]	166	13	103	5	620	2,165
Total	25,346	24,681	32,142	26,288	31,740	37,421
Grand total	44,284	37,100	45,533	47,320	51,240	54,748

[1] Includes primary metal to produce small quantities of investment castings.
[2] Included with "Other" to avoid disclosing individual company confidential data.
[3] Before 1961, included with "Other alloys".
[4] Quantity used for reduction of uranium was not reported.
[5] Includes primary metal for experimental purposes, debismuthizing lead, and producing nodular iron, secondary magnesium alloys, and powder.

A magnesium alloy (LA 141A) containing 13 to 14 percent lithium and 1 percent aluminum was used extensively as a structural material in the U.S. Air Force Agena space vehicle. It is about half as dense as aluminum and was available in plates, sheets, and as extrusions.

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[3] Eade, R. W. Nuclear Reactors Use Magnesium Castings. Foundry, v. 92, No. 6, June 1964, pp. 152, 155.

PRICES

The quoted base price of primary magnesium ingot in standard 42-pound pig form remained at 35.25 cents per pound, f.o.b. U.S. plants. There was pressure, however, to bring the U.S. price closer to world prices and more competitive with other metals. The major diecasting alloy (AZ 91B) was being sold for 30 cents per pound. The Dow Chemical Co. offered to lower prices to aluminum smelters and alloyers who contract to buy 50 percent of their magnesium from Dow by 1 cent per pound in 1964, 1965, and 1966 and 0.5 cents per pound per year for the succeeding 4 years reaching 30.25 cents per pound by 1970.

STOCKS

On December 31, 1964, producer and consumer stocks were 12,616 tons of primary magnesium and 4,100 tons of primary magnesium alloy ingot. Stocks at yearend 1963 were 11,190 tons of primary magnesium and a corrected figure of 7,340 tons of primary magnesium alloy ingot. The national strategic stockpile contained 171,383 tons of magnesium.

TABLE 4.—Stock and consumption of new and old magnesium scrap in the United States in 1964

(Short tons)

Scrap item	Stocks, Jan. 1[r]	Receipts	Consumption			Stocks Dec. 31
			New scrap	Old scrap	Total	
Cast scrap	404	3,639	153	3,663	3,816	227
Solid wrought scrap	321	3,120	3,066		3,066	375
Borings, turnings, drosses, etc.	184	2,269	2,283		2,283	170
Total	909	9,028	5,502	3,663	9,165	772

[r] Revised.

FOREIGN TRADE

The imports of 2,741 tons (magnesium content) came from 15 countries; 2,006 tons from Canada; 223 tons from Netherlands; 133 tons from West Germany; 132 tons from the United Kingdom; 100 tons from Norway; 48 tons from Denmark; 29 tons from Sweden; 17 to 20 tons each from Republic of South Africa, Japan, and Taiwan; and less than 6 tons each from Canal Zone, Libya, Bermuda, Honduras and Mexico.

The duty on magnesium and scrap remained at 40 percent ad valorem; alloys (magnesium content) were 16 cents per pound plus 8 percent ad valorem; and wrought magnesium was 13.5 cents per pound plus 7 percent ad valorem. Suspension of duty on metallic scrap continued to June 30, 1965.

TABLE 5.—U.S. imports for consumption and exports of magnesium

Year	Imports					
	Metallic and scrap		Alloys (magnesium content)		Powder, sheets, tubing, ribbons, wire, and other forms (magnesium content)	
	Short tons	Value	Short tons	Value	Short tons	Value
1955–59 (average)	917	$480,261	21	$146,180	11	$53,603
1960	401	202,087	28	287,916	4	60,623
1961	1,005	482,907	31	170,304	5	80,419
1962	2,359	1,079,819	53	106,242	35	83,399
1963	r 1,850	733,248	r 485	r 660,135	18	112,146
1964	2,227	889,980	474	710,299	40	70,176

Year	Exports					
	Metal and alloys in crude form and scrap		Semifabricated forms, n.e.c.		Powder	
	Short tons	Value	Short tons	Value	Short tons	Value
1955–59 (average)	2,929	$1,805,001	538	$876,918	23	$43,940
1960	4,467	2,658,480	658	1,037,325	7	23,048
1961	6,160	3,639,669	488	878,815	33	78,297
1962	6,426	3,656,316	594	1,002,977	21	52,980
1963	r 15,484	r 8,599,260	690	1,187,912	33	87,075
1964	15,949	8,848,490	862	1,354,014	8	29,491

r Revised.

Source: Bureau of the Census.

TABLE 6.—U.S. exports of magnesium, by classes and countries

(Short tons)

Destination	1963			1964		
	Primary metal, alloys, and scrap	Semifabricated forms, n.e.c.	Powder	Primary metal, alloys, and scrap	Semifabricated forms, n.e.c.	Powder
North America:						
Canada	597	207	2	1,726	354	1
Mexico	343	68	(1)	269	67	---
Other	---	5	---	---	5	(1)
Total	940	280	2	1,995	426	1
South America:						
Brazil	r 1,208	1	---	896	(1)	---
Venezuela	4	36	1	---	19	---
Other	22	27	---	32	23	1
Total	r 1,234	64	1	928	42	1
Europe:						
Belgium-Luxembourg	7	21	2	6	15	1
France	177	6	(1)	450	31	1
Germany, West	r 10,964	50	---	10,663	93	---
Italy	72	13	(1)	45	18	---
Netherlands	r 392	9	---	51	8	(1)

See footnotes at end of table.

TABLE 6.—U.S. exports of magnesium, by classes and countries—Continued

(Short tons)

Destination	1963			1964		
	Primary metal, alloys, and scrap	Semifabricated forms, n.e.c.	Powder	Primary metal, alloys, and scrap	Semifabricated forms, n.e.c.	Powder
Europe—Continued						
Spain	144	(1)	2	33	----------	----------
Switzerland	----------	3	(1)	121	9	(1)
United Kingdom	r 381	11	(1)	400	19	2
Yugoslavia	122	----------	----------	301	----------	----------
Other	10	15	7	28	40	----------
Total	r 12,269	128	11	12,098	233	4
Asia:						
India	r 238	7	16	24	2	----------
Israel	9	5	2	23	4	2
Japan	r 562	167	----------	552	101	----------
Other	1	9	1	3	26	----------
Total	r 810	188	19	602	133	2
Africa	11	30	----------	55	23	(1)
Oceania	220	(1)	----------	271	5	----------
Grand total	r 15,484	690	33	15,949	862	8

r Revised.

[1] Less than 1 ton.

Source: Bureau of the Census.

WORLD REVIEW

Canada.—About 76 percent of the January–September Canadian production was exported. Based on value, about 35 percent of the exports went to the United Kingdom compared with 58 percent during 1963. Exports to West Germany increased to 32 percent from 14 percent in 1963. Supply from a new magnesium plant at Hopton, England, probably accounted for the decreased British demand.

TABLE 7.—World production of primary magnesium, by countries [1]

(Short tons)

Country	1955-59 (average)	1960	1961	1962	1963	1964
Canada	7,718	7,289	7,635	8,816	8,904	9,021
China e	1,000	1,000	1,000	1,000	1,000	1,000
France	1,789	2,359	2,282	2,392	1,981	1,087
Germany, West	375	330	440	550	550	550
Italy	4,214	6,004	6,365	6,288	6,092	e 6,100
Japan	707	2,363	2,477	2,301	2,689	e 3,200
Norway	9,165	11,373	16,018	16,400	22,700	e 25,000
U.S.S.R. e	18,900	27,600	34,000	35,000	35,000	35,000
United Kingdom [2]	3,796	4,119	5,824	5,559	5,219	e 5,500
United States	54,375	40,070	40,745	68,955	75,845	79,488
World total e	102,000	102,500	116,800	147,300	160,000	165,900

e Estimate.

[1] This table incorporates some revisions. Data do not add exactly to totals shown because of rounding where estimated figures are included in the detail.

[2] Primary metal and remelt alloys.

France.—The electrolytic magnesium plant of Société d'Electrochime, Electrometallurgie, et des Aciéries Electriques d'Ugine (Ugine) at Jarrie was closed in November. The quota of duty-free magnesium was increased to 400 tons in 1964—twice the 1963 quota.

Experimental and developmental work on thermo reduction of magnesia in France was the basis for a new plant under construction at Marignac in the French Pyrenees. Plans for the construction showed four furnaces rated at 1,600 kilowatts and capable of producing 3,500 tons per year for the first stage and provision to add two more furnaces to increase production to 5,500 tons.

Three French firms own the plant; Pechiney, Compagnie de Produits Chimiques et Electrometallurgiques (35 percent), Ugine (35 percent) and Société des Produits Azotes (SPA) (30 percent). SPA produces the necessary ferrosilicon at Marignac in a 12,000 kilowatt Elkem furnace. Dolomite is available at a quarry several miles from the plant.[4]

Germany, West.—Import records indicated that consumption was about the same as in 1963 which was about 38,000 tons. More than half was imported from Norway and about a quarter from the United States.

During 1964 West Germany raised the quota for duty-free imports of magnesium from countries outside the European Economic Community to 31,000 tons because Italy, the major supplier in the Community, was unable to meet requirements of the motor industry.

India.—India announced plans to build a 250-ton capacity magnesium pilot plant to be operational by the end of 1965.

Japan.—The following amounts of secondary magnesium were produced in Japan: 1960, 3,327; 1961, 3,060; 1962, 2,130; and 1963, 1,556 short tons. Production in 1964 was not available.

Norway.—Norsk Hydro Elektrisk A/S, the sole magnesium producer in Norway, announced plans to increase annual capacity from 24,000 tons to 31,000 tons. Most of the 1964 production went to West Germany.

U.S.S.R.—Three papers presented at the 1963 World Magnesium Congress on the Soviet magnesium industry and research were abstracted.[5] No new information was provided to alter the Bureau of Mines estimates of U.S.S.R. magnesium production. The industry was reported to be operating reduction cells on currents exceeding 100,000 amperes, and with energy consumption as low as 16,000 kilowatt-hours (direct current) per ton. Wide acceptance by designers of magnesium structural alloys was reported.

TECHNOLOGY

Progress continued in development of more efficient magnesium production techniques and of improved magnesium alloys. Studies were conducted on corrosion resistance, improvements of mechanical properties, and structural problems of various bonding methods applied to magnesium components.

The status of the magnesium industry was surveyed in a comprehensive review of the technology and economics of competitive materials and on expansion of markets.[6] Problems of electrolytic and thermal reduction methods encountered at domestic and foreign operations and U.S. Government operations during World War II were discussed on a comparative and individual basis.

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[4] Faure, C., and J. Marchal. Magnesium by the Magnetherm Process. J. Metals, v. 16, No. 9, September 1964, pp. 721–723.

[5] Journal of Metals. The Production of Magnesium and Its Alloys in the U.S.S.R., v. 16, No. 7, July 1964, pp. 556–557.

[6] Hanawalt, J. D. Present Status and Future Trends in the Production of Magnesium. J. Metals, v. 16, No. 7, July 1964, pp. 559–563.

Technological and cost evaluations were made of thermic magnesium production in two hypothetical plants based on carbothermic and metallothermic methods. Proposed process modifications on the carbothermic method indicated a need for further research on the use of liquid hydrocarbon for quenching magnesium vapor and continous retorting of the quenched product. Suggested improvements for the metallothermic method include use of aluminum silicon as a reductant and a continuous or larger batch reduction method. An estimate of the capital cost of a 24,000 ton hypothetical carbothermic was about $58 million, and annual operating costs were about $16.7 million. The capital cost was about $20.8 million for a 12,000-ton silcothermic plant, and annual operating costs were about $9.8 million.[7]

The Beudéan experimental magnesium plant, in the French Pyrenees, produces about 1,000 tons of magnesium per year using the magnetherm semicontinuous process in which 1 ton of magnesium is produced from about 12 tons of dolomite (20.5 percent MgO), 1 ton of ferrosilicon (75 percent Si), and 1 ton of calcined bauxite (85 percent Al_2O_3). The ferrosilicon, calcined dolomite, and calcined bauxite were fed from individual bins into an electric furnace with an inside operating pressure of 25 millimeters of mercury. In the presence of Al_2O_3, the solidification temperature of the slag was as low as 1,500° C. The slag was removed by ladle from a tap, and the magnesium was collected at the bottom of the condensor in a crucible which was disconnected for transporting the magnesium to a foundry where, after remelting and refining, it is poured into ingot molds.

This study was the basis for the present construction of a new furnace at Marignac in the French Pyrenees, planned for four furnaces rated at 1,600 kilowatts and capable of producing 3,500 tons per year.[8]

Volkswagenwerk, AG of West Germany initiated new techniques to lower the costs of magnesium castings used in the transmission and engine housing of its rear engined autos.[9] Magnesium was used instead of heavier aluminum in order to achieve the proper weight distribution between the two axles and overcome the major fault of a rear-mounted engine. Time was saved by converting from permanent mold casting of the magnesium crankcase to pressure die casting. This was improved by using nitrogen gas under pressure to force the metal into the metering chamber and thus eliminating the need for a pump. The feeder pipes heated by gas burners were replaced by more efficient electric heated tubes. Other improvements are in process to lowér the costs of magnesium casting.

A method of degassing a melt of magnesium-base alloy was patented by which chlorine gas is injected into the center part of the melt shielded from the remainder by a circular baffle extending from the top to about the bottom.[10]

A magnesium-base alloy extruded at 700° F to 900° F consisting of 1.5 to 3.25 weight-percent zinc, 0.7 to 1.5 weight-percent rare-earth metal, 0.5 to 0.8 percent zirconium, and the balance magnesium with a minimum tensile yield strength of 23,000 pounds per square inch (p.s.i.) in the transverse direction of extruding was patented.[11]

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[7] Dean, K. C., D. A. Elkins, and B. H. Clemmons. An Evaluation of Thermic Production Methods for Magnesium. J. Metals, v. 16, July 1964, pp. 564–568.

[8] Faure, C., and J. Marchal. Magnesium by the Magnetherm Process. J. Metals, v. 16, No. 9, September 1964, pp. 721–723.

[9] Modern Metals. Volkswagen, World's Largest Magnesium User Reveals Cost-Cutting Techniques, v. 20, No. 7, August 1964, pp. 42, 46, 48.

[10] Peters, Adolph T. (assigned to The Dow Chemical Co., Midland, Mich., a corporation of Delaware). Degassing Magnesium-base Alloy. U.S. Pat. No. 3,123,467, Mar. 3, 1964.

In the production of heat transfer units for the Polaris missile by investment casting, close tolerances were maintained as required.[12] Costs were 25 percent of the cost of a machined part.

The National Aeronautics and Space Administration released data on physical properties of three magnesium lithium alloys, alloys LA141A, LA91A, and LAZ933 which have ultimate tensile strengths of 21,000 p.s.i., 22,000 p.s.i., and 30,000 p.s.i. respectively.[13] Alloy LA141 is available commercially and alloy LA91 is available on custom orders. Both were developed in the Battelle Memorial Institute, Columbus, Ohio research program. Alloy LAZ933 was just recently developed and was not ready for commercial use.

An article was published describing the lack of stability of magnesium-lithium-base alloys during aging at slightly elevated temperatures using data obtained by X-ray diffraction.[14]

A fully detailed report on the evaluation of chemical and mechanical properties of aluminum and magnesium as used in reactors was published.[15]

The problem of structural weakness caused by voids or airpockets resulting from vibration, impact or heat environment in the joints of magnesium components bonded by adhesive was solved by employing vacuum pressure, and heat to the assembly.[16] The interfaces are machined to a close fit, heated to 200° F, and the assembly placed in a vacuum pressure vessel which was heated to 200° F and evacuated. Epoxy achesive was forced into the bond line gap through a feeder line. The vacuum was relieved, and the vessel was pressurized to 90 p.s.i. using nitrogen. This was maintained for 16 hours at 200° F.

Adhesive bonding of magnesium joints with its uniformly distributed stresses eliminates the need to specify thicker sections to overcome stress concentrations produced by riveted or spot welded joints.[17] The article emphasizes design for uniform distribution of working stresses in shear or tension and avoidance of peel or cleavage stresses induced by tilting of an adhesive bonded lap joint heavily loaded in tension. The problem can be avoided by using joggle lap or beveled lap joints. The article includes a table on the characteristics of various adhesives and charts on the effect of lap widths and temperatures on the strength of adhesive bonded joints of magnesium.

Results of the various welding procedures and conditions as applied to magnesium were described in an article.[18] Magnesium can be welded to itself or to magnesium alloys with a possible weld strength of 90 percent or better of the base metal.

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[11] Hershey, Gordon F., George S. Foerster, and Sidney L. Couling (assigned to The Dow Chemical Co.) Magnesium-Base Alloy. U.S. Pat. 3,131,095, Apr. 28, 1964.

[12] Modern Metals. Investment Casting Cuts Cost of Intricate Magnesium Parts 75 percent, v. 20, No. 4, May 1964, p. 70.

[13] NASA Tech Brief. Lightweight Magnesium-Lithium Alloys Show Promise. Brief 63–19389, June 1964, 2 pp.

[14] Rinnovatore, J. V., and M. Schwartz. The Proposed Structure of the Transition Phase and Stability in Mg—Li—Al—Zn. J. Inst. Metals (London), v. 92, No. 6, February 1964, pp. 188–189.

[15] Wyatt, L. M. Aluminium and Magnesium in Reactors. Pt. I, Metal Industry (London), v. 104, No. 8, Feb. 20, 1964, pp. 252–255; pt. II, No. 9, Feb. 27, 1964, pp. 288–291.

[16] Product Engineering Bonding, v. 35, No. 24, Nov. 23, 1964, p. 57.

[17] Church, F. L. Bonding Part 6: Adhesives and Techniques for Magnesium. Modern Metals, v. 20, No. 8, September 1964, pp. 56, 58, 60.

[18] Materials in Design Engineering. Arc Welding-Magnesium and Magnesium Alloys, v. 60, No. 6, November 1964, p. 114.

A chemically milled smooth surface of magnesium is more corrosive resistant than a rough as-cast surface due to the reduction of area.[19] Anodic treatment offers additional protection.

Results of 10-year exposure tests to marine atmosphere on various cast magnesium alloys were published.[20] The specimens showed little sign of corrosion.

A method for reducing oxidation of magnesium sheaths, in a nuclear reactor by bubbling at least part of the oxidizing atmosphere through a dilute aqueous solution entraining a minimum of 2 millionths of a gram of fluorine per liter of oxidizing atmosphere at 250–500° C was patented.[21]

A method was patented whereby a mixture of magnesium oxide-containing material, lime, and ferrosilicon was heated to 1,450° C to 1,500° C and then raised to 1,600° C to effect liquid phase reduction, thereby, forming magnesium vapor and molten slag.[22]

A method was patented, whereby, in the thermal production of magnesium, a slag with a low melting temperature was formed in a molten condition for removal by tapping.[23]

Due to the incompatibility of aluminum and zirconium in the same alloy, magnesium alloys containing both of these metals have not been produced commercially. Studies were conducted on magnesium-rich magnesium-aluminum-zirconium alloys.[24] Two intermetallic compounds, $ZrAl_2$ and $Mg_{17}Al_{12}$, were identified.

Early results were promising in experimental injection of magnesium powder into the combustion chamber of oil fired boilers. The use of magnesium reduced acid corrosion and acid emission and prevented the high-temperature corrosion caused by deposition of vanadium oxide.[25]

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[19] Foundry. Surface Preparation Increases Corrosion Resistance of Magnesium Castings, v. 92, No. 3, March 1964, pp. 68–69.

[20] Light Metals (London). 10-Year Test of Cast Magnesium Alloys, v. 27, No. 311, April 1964, pp. 46–48.

[21] Caillat, Roger (Sevres, France), and Raymond Darras (Gif-sur-Yvette, France) (assigned to Commissariat a' L'Energie Atomique, Paris, France). Process For Preventing Oxidation of Nuclear Reactor Coolant Channel Magnesium Sheaths. U.S. Pat. 3,119,745, Jan. 28, 1964.

[22] Aoyama, Kozo, Tokyo, Japan (assigned to Asahi Kasei Kogyo Kabushiki Kaisha, Osaka, Japan, a corporation of Japan). Producing Metallic Magnesium From A Magnesium Oxide Containing Material. U.S. Pat. 3,114,627, Dec. 17, 1963.

[23] Munekata, Eiji, and Suzuki, Akira (assigned to Asahi Kasei Kogyo Kabushiki Kaisha, Osaka, Japan, a corporation of Japan). Method of Producing a Slag Having the Low Melting Point in the Manufacture of Metallic Magnesium by Reduction of Magnesia with Ferrosilicon. U.S. Pat. 3,129,094, Apr. 14, 1964.

[24] Crosby, R. L., and L. W. Higley, Jr. Intermetallic Compounds in Magnesium-Rich Magnesium-Aluminum-Zirconium Alloys. BuMines Rept. of Inv. 6498, 1964, 13 pp.

[25] Metallurgia (Manchester, England). Magnesium Injection into Oil Fired Boilers, v. 69, No. 416, June 1964, p. 262.

Magnesium Compounds

By Lloyd R. Williams[1]

❖

WORLD PRODUCTION of magnesite was slightly above that of 1963. U.S.S.R. continued as principal producer accounting for 32 percent of the world total. Production of magnesite in the United States increased. U.S. exports of dead-burned magnesite and magnesia increased 2 percent above 1963. The value of exported magnesite and magnesia, other than dead-burned, was more than double that of 1963.

DOMESTIC PRODUCTION

Nevada and Washington supplied all of the crude magnesite produced in 1963. Northwest Magnesite Co., a subsidiary of Harbison-Walker Refractories Co., was the sole producer in Washington and Basic Inc. in Nevada. No brucite was reported as mined in 1964. Agro Minerals, Inc. did not report production of epsomite in Washington.

TABLE 1.—Salient magnesium compounds statistics

(Thousand short tons and thousand dollars)

	1955–59 (average)	1960	1961	1962	1963	1964
United States:						
Crude magnesite: Production:						
Quantity	588	499	604	492	528	W
Value[1]	$2,657	$2,051	$3,129	$2,287	$1,779	W
Caustic-calcined magnesia:						
Sold or used by producers:						
Quantity	46	66	80	[r] 63	135	160
Value[2]	$2,802	$4,292	$5,004	[r] $3,857	$7,865	$9,392
Imports for consumption:						
Value	$228	$213	$226	$395	$500	$493
Exports: Value	$1,171	$686	$535	$427	$678	$1,654
Refractory magnesia:						
Sold or used by producers:						
Quantity	450	506	599	576	713	840
Value	$24,824	$30,863	$35,408	$35,186	$44,378	$49,025
Imports: Value	$6,311	$7,576	$3,611	$5,520	$4,593	$3,180
Exports: Value	$2,078	$5,988	$7,988	$5,363	$5,620	$5,554
Dead-burned dolomite:						
Sold or used by producers:						
Quantity	2,090	1,949	1,983	1,857	1,949	2,168
Value	$33,098	$32,468	$32,513	$31,059	$33,058	$37,961
Imports: Value	$521	$550	$233	$245	$455	$1,165
World: Crude magnesite: Production:						
Quantity	5,500	7,850	8,300	8,750	9,200	10,000

W Withheld to avoid disclosing individual company confidential data.

[r] Revised.

[1] Partly estimated: Most of the crude is processed by mining companies, and very little enters the open market.

[2] Includes specialty magnesia of high unit value.

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[1] Commodity specialist, Division of Minerals.

Approximately 82 percent of the dead-burned dolomite was produced in Ohio, Illinois, and Pennsylvania. Southwestern Superior Products, Roundrock, Tex., started production of dead-burned dolomite. Washington and North Carolina accounted for the production of crude olivine which was more than double the 1963 output.

Production of hydrous magnesium sulfate increased 17 percent and specified magnesias 9 percent.

Michigan led in the production of refractory magnesia which was also produced in California, Florida, Mississippi, Nevada, New Jersey, and Texas.

CONSUMPTION AND USES

Consumption of olivine was 13 percent more than in 1963. Consumption of crude magnesite and brucite also increased.

Consumption of caustic calcined magnesia made from magnesite, dolomite, well brines, sea water, and sea water bitterns amounted to 160,000 short tons, an increase of 19 percent above 1963; refractory magnesia from the same sources amounted to 840,000 tons, an increase of 18 percent. Consumption of dead-burned dolomite increased 11 percent; anhydrous magnesium chloride 6 percent, and magnesium hydroxide 14 percent. Consumption of hydrous magnesium chloride decreased 3 percent.

Consumption of hydrous magnesium sulfate increased 20 percent above that in 1963; specified magnesias increased 24 percent, and precipitated magnesium increased 4 percent. Consumption of magnesium trisilicate was not reported.

General Refractories Co. announced receipt of an order from Eregli Demir Ve Celik Fabrikalari (Erdemir), Eregli, Turkey, for more than 7,500 tons of a tar bonded magnesite refractory brick, for use in a basic oxygen furnace under construction in Eregli, Turkey.[2]

Langbeinite ($K_2SO_4 \cdot 2MgSO_4$) has a suitable ratio of potassium and magnesium molecular-equivalent to use as a fertilizer for a balanced plant nutrition, particularly for legumes.[3]

TABLE 2.—Dead-burned dolomite sold in and imported into the United States

Year	Sales of domestic product		Imports[1]	
	Short tons	Value (thousands)	Short tons[2]	Value (thousands)
1955-59 (average)	2,090,250	$33,098	8,319	$521
1960	1,949,260	32,468	12,932	550
1961	1,982,759	32,513	4,256	233
1962	1,857,438	31,059	4,456	245
1963	1,948,953	33,058	8,890	455
1964	2,167,523	37,961	28,876	1,165

[1] Dead-burned basic refractory material comprising chiefly magnesium and lime.
[2] Includes weight of immediate container.

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[2] Blast Furnace & Steel Plant. Grefco Receives Large Order For Basic Oxygen Furnace Refractories. V. 52, No. 12, December 1964, p. 1172.

[3] Albrecht, William A. The Future of Langbeinite In The Maintenance of Soils. Agricultural Chem., V. 19, No. 6, June 1964, pp. 18-19, 21.

TABLE 3.—Specified magnesium compounds produced, sold, and used by producers in the United States

Year and product[1]	Plants	Produced (short tons)	Sold		Used (short tons)
			Short tons	Value (thousands)	
1963:					
Specified magnesias (basis, 100 percent MgO), U.S.P. and technical:					
Extra-light and light	3	3,290	2,006	$1,306	------------
Heavy	2	3,782	3,661	1,527	------------
Total	[2] 4	7,072	5,667	2,833	------------
Precipitated magnesium carbonate	5	11,941	4,336	936	7,649
Magnesium hydroxide, U.S.P. and technical (basis, 100 percent $Mg(OH)_2$)	7	430,830	277,287	7,425	152,427
Magnesium chloride	7	290,759	13,608	945	[2] 275,735
1964:					
Specified magnesias (basis, 100 percent MgO), U.S.P. and technical:					
Extra-light, light, and heavy	4	7,737	7,045	3,373	------------
Precipitated magnesium carbonate	5	11,583	4,387	954	8,086
Magnesium hydroxide, U.S.P. and technical (basis, 100 percent $Mg(OH)_2$)	7	500,352	322,105	8,537	169,822
Magnesium chloride	7	305,602	13,327	936	[2] 292,521

[1] In addition, magnesium sulfate and trisilicate were produced.
[2] Greater part used for magnesium metal.

TABLE 4.—Domestic consumption of caustic-calcined magnesia by uses

(Percent)

Use	1960	1961	1962	1963	1964
Oxychloride and oxysulfate cement	47	33	25	16	12
Rayon	3	3	2	8	7
Fertilizer	1	(2)	(2)	1	1
85-percent MgO insulation	3	8	2	[r] 6	2
Rubber	4	3	4	[r] 1	1
Fluxes	(1)	(2)	(2)	(2)	2
Refractories	9	27	28	45	52
Chemical processing	3	1	1	3	2
Uranium processing	7	5	4	2	(2)
Pulp and paper	(3)	(3)	(3)	12	11
Miscellaneous (including chemicals)	23	20	34	6	10
Total	100	100	100	100	100

[r] Revised.
[1] Less than 1 percent.
[2] Less than 0.5 percent.
[3] Included with miscellaneous.

PRICES

In January the price of magnesium carbonate U.S.P. grade in carload lots decreased from 14.5 to 14.0 cents per pound. Prices of other magnesium compounds remained unchanged throughout 1964.

FOREIGN TRADE

Caustic calcined magnesia was imported from Australia for the first time but the quantity was not sufficient to offset a 70 percent decrease in imports from the Netherlands and total imports for consumption decreased 6 percent from 1963.

Imports for consumption of dead-burned, grain magnesia and periclase decreased 30 percent; magnesium carbonate (precipitated) increased about 80 percent; and magnesium sulfate (epsom salt) increased 12 percent.

Exports of dead-burned magnesite and magnesia to Japan and West Germany dropped by more than half for the second successive year. However, total exports increased 2 percent. Deliveries to Mexico, the principal recipient, increased 36 percent.

TABLE 5.—U.S. imports for consumption of crude and processed magnesite by countries

Country	1963		1964	
	Short tons	Value	Short tons	Value
Crude magnesite:				
Europe: Austria	-----	-----	2	$490
Lump or ground caustic-calcined magnesia:				
Europe:				
Austria	746	$27,791	700	25,519
Greece	28	1,648	65	4,814
Netherlands	1,445	86,628	430	30,467
Switzerland	1	119	-----	-----
Yugoslavia	441	15,646	330	13,872
Asia:				
India	7,256	367,303	6,867	325,128
Japan	-----	-----	1	390
Pakistan	-----	-----	76	4,186
Africa:				
British East Africa	15	804	-----	-----
Tanganyika	-----	-----	144	7,376
Oceania: Australia	-----	-----	771	81,159
Total	9,932	499,939	9,384	492,911
Dead-burned and grain magnesia and periclase:				
North America: Canada	82	19,052	39	4,042
Europe:				
Austria	56,162	2,868,242	22,369	1,198,340
Greece	11,035	707,184	14,009	886,018
Italy	-----	-----	1,747	76,458
Spain	5	265	-----	-----
United Kingdom	-----	-----	28	3,055
Yugoslavia	19,346	998,077	21,904	1,011,875
Total	86,630	4,592,820	60,096	3,179,788

Source: Bureau of the Census.

TABLE 6.—U.S. imports for consumption of magnesium compounds

Year	Oxide or calcined magnesia		Magnesium carbonate (precipitated)		Magnesium chloride (anhydrous and n.s.p.f.)		Magnesium sulfate (epsom salt)		Magnesium salts and compounds n.s.p.f.[1] [2]		Manufactures of carbonate of magnesia	
	Short tons	Value	Short tons	Value	Short tons	Value	Short tons	Value	Short tons	Value	Short tons	Value
1955–59 (average)	270	$90,002	306	$68,413	527	$16,675	11,108	$261,190	1,116	$55,516	10	$2,425
1960	266	65,973	346	83,737	1,174	53,920	10,121	240,661	3,036	94,267	28	6,896
1961	248	61,208	342	73,602	1,012	31,375	10,031	231,022	3,796	117,393	6	3,155
1962	182	47,766	398	94,421	1,474	127,090	9,297	209,787	3,505	106,729	4	2,823
1963	93	39,436	623	118,895	668	22,611	8,543	186,997	3,625	128,111	-----	-----
1964	127	50,249	1,112	210,081	752	24,487	9,549	212,380	1,051	58,406	-----	-----

[1] Not specifically provided for.
[2] Includes magnesium silicofluoride or fluosilicate and calcined magnesia.

Source: Bureau of the Census.

TABLE 7.—U.S. exports of magnesite and magnesia, by countries

Destination	Magnesite and magnesia, dead-burned				Magnesite and magnesia (except dead-burned) and manufactures, n.e.c.[1]	
	1963		1964		1963	1964
	Short tons	Value	Short tons	Value	Value	Value
North America:						
Canada	15,275	$1,266,086	17,886	$1,384,324	$167,229	$200,534
Costa Rica	----	----	----	----	5,406	62,296
Mexico	18,405	1,214,674	25,131	1,704,430	24,750	74,370
Other	4	512	85	13,114	22,623	30,768
South America:						
Argentina	114	13,449	592	75,254	1,046	2,354
Brazil	4	2,285	1	594	23,575	595
Chile	298	23,430	1,188	91,703	12,456	76,427
Colombia	153	22,855	----	----	4,108	2,993
Peru	1,101	69,078	1,104	69,555	6,603	11,852
Venezuela	----	----	1,847	125,692	15,310	10,193
Other	----	----	1	470	----	1,231
Europe:						
Belgium-Luxembourg	8	3,221	19	14,041	15,132	16,363
Denmark	14	9,874	----	----	6,808	21,288
France	363	107,525	524	248,314	1,964	1,915
Germany, West	3,046	329,181	1,370	240,119	9,122	326,725
Italy	171	35,028	267	44,413	1,320	19,617
Netherlands	24	8,120	706	57,187	4,984	724
Portugal	130	16,466	----	----	354	432
Spain	14	6,026	42	3,223	65,710	45,681
Sweden	82	45,051	68	35,655	24,733	33,427
Switzerland	34	14,516	33	12,176	4,364	10,032
United Kingdom	5,990	521,341	6,291	212,096	64,970	390,033
Other	31	15,738	36	12,683	2,160	4,437
Asia:						
Japan	12,203	701,004	5,123	301,772	26,952	37,412
Korea, South	1,484	77,438	1,219	68,050	----	----
Philippines	88	12,683	3	1,600	25,447	3,197
Other	4	2,715	11	1,851	81,075	50,346
Africa:						
South Africa, Republic of	132	35,629	56	24,128	8,163	28,094
Other	2	774	2	820	2,168	24,306
Oceania:						
Australia	18,430	1,047,688	15,715	810,618	35,683	119,841
New Zealand	25	17,544	----	----	13,403	46,086
Total	77,629	5,619,931	79,320	5,553,882	677,618	1,653,569

[1] Not elsewhere classified.

Source: Bureau of the Census.

WORLD REVIEW

Argentina.—Machinery for the first basic refractory plant in Argentina was shipped from the United States by General Refractories Co. (GREFCO). The plant, to cost $2 million, will be operated by a wholly owned GREFCO subsidiary.

Canada.—Canadian Magnesite Mines Co. produced experimental quantities of a concentrate analyzing 97.5 to 98 percent magnesium carbonate, 1.8 percent Fe_2O_3, and 0.2 percent silica. The company was constructing a multiple hearth furnace at North Bay, Ontario to calcine magnesite mined from a deposit south of Timmins, Ontario.

The Ontario Minnesota Pulp and Paper Co., at Kenora, Ontario, was changing its sulfite pulping process from a calcium base to a magnesium base. The changeover primarily was made to increase the strength of newsprint and to permit greater use of jack pine wood pulp which is usually abundant.

TABLE 8.—World production of magnesite by countries [1] [2]

(Short tons)

Country [1]	1955–59 (average)	1960	1961	1962	1963	1964 [p]
North America: United States	587,687	498,528	603,656	492,471	527,655	W
South America:						
Brazil	27,913	69,793	84,549	103,348	99,536	[3] 99,536
Colombia	[4] 11	------	110	110	276	[2] 276
Europe:						
Austria	1,250,096	1,791,701	1,982,704	1,771,863	1,447,099	1,826,058
Czechoslovakia [e]	330,000	470,000	550,000	580,000	580,000	580,000
Greece	81,806	206,451	163,573	299,789	[e] 275,000	[e] 220,000
Italy	6,510	6,584	7,478	9,275	7,512	6,954
Norway	400	------	------	------	------	------
Poland	18,556	23,900	29,900	37,600	29,300	(5)
Spain	36,065	53,239	91,702	78,691	93,315	[3] 93,315
U.S.S.R. [e]	1,650,000	2,650,000	2,760,000	2,760,000	2,980,000	3,090,000
Yugoslavia	218,648	277,613	301,002	411,561	454,107	548,311
Asia:						
China [e]	740,000	1,100,000	770,000	880,000	990,000	1,100,000
India	111,142	172,325	231,203	234,669	258,564	228,985
Korea, North [e]	35,000	55,000	220,000	550,000	880,000	990,000
Pakistan	[6] 155	486	180	336	968	680
Turkey	618	17	2,414	10,736	19,750	43,065
Africa:						
Kenya	763	33	1,930	------	288	187
Rhodesia (formerly Southern)	4,626	8,031	13,880	11,620	12,068	42,411
South Africa, Republic of	45,547	66,793	67,732	102,352	108,309	93,443
Tanzania (exports)	276	126	46	------	94	546
Oceania:						
Australia	75,222	69,626	110,651	69,654	63,780	38,640
New Zealand	654	891	650	711	875	676
World total (estimate) [1] [2]	5,500,000	7,850,000	8,300,000	8,750,000	9,200,000	10,000,000

[e] Estimate. [p] Preliminary. W Withheld to avoid disclosing individual company confidential data.

[1] Quantities in this table represent crude magnesite mined. Magnesite is also produced in Bulgaria and Canada, but data on tonnage of output are not available; estimates by author of chapter included in total.

[2] This table incorporates some revisions. Data do not add exactly to totals shown because of rounding where estimated figures are included in the detail.

[3] 1963 data.

[4] Average annual production 1958–59.

[5] Data not available; estimate by author of chapter included in total.

[6] Average annual production 1957–59.

Czechoslovakia.—Plans to open a new magnesite mine at Tepla Voda were announced.

Greece.—In 1963, the average f.o.b. Greek port price for magnesite was $8.40 per short ton. Average f.o.b. quotations for processed magnesite (including both caustic-calcined and dead-burned magnesite) was $40 per short ton.

The Grecian Magnesite Co., a leading producer of caustic-calcined magnesite, placed an order in Hungary for a rotary kiln with a capacity of 60 to 70 tons per day to be installed at its magnesite mining property of Yerakini, Chalkidiki. Greek American Mining Co., S.A., an affiliate of General Refractories Co. of Philadelphia, announced plans to build a magnesite and chrome-magnesite refractory plant in northern Greece.[4]

India.—Reserves of magnesite in India amount to over 100 million tons (metric). Of this, over 80 million tons is in the Salem District of Madras, and 20 million tons on Almora District of Uttar Pradesh.

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[4] Mining Journal (London). Magnesite Refractory Plant in Greece. V. 263, No. 6724, July 3, 1964, p. 9.

TABLE 9.—Austria: Exports of magnesia and magnesite brick by countries[1]

(Short tons)

Destination	Magnesia				Magnesite brick	
	Caustic-calcined		Refractory			
	1963	1964	1963	1964	1963	1964
North America: United States	749	701	50,548	48,012	207	1
South America:						
Argentina	----------	63	1,652	2,962	2,727	3,024
Brazil	44	----------	26	----------	1,030	425
Chile	----------	3	617	1,035	981	907
Colombia	12	6	55	34	875	421
Europe:						
Belgium-Luxembourg	285	176	1,499	1,394	4,960	5,506
Bulgaria	11	----------	96	87	932	321
Czechoslovakia	3,833	591	50	----------	258	1,115
Denmark	1,081	2,382	679	138	4.514	4.049
Finland	----------	3	531	1.005	1,858	2,943
France	1,105	1,382	12,413	18,039	18,967	23,576
Germany, West	85,043	93,255	75,876	114,328	18,937	26,215
Greece	----------	----------	328	423	1,514	1,829
Hungary	2,880	2.234	13,032	11,310	----------	----------
Italy	4,441	4,473	10,758	10,890	11,059	6,129
Netherlands	354	910	416	229	1,212	565
Norway	11	31	452	694	4,738	3,723
Poland	----------	----------	----------	109	791	1,435
Portugal	11	40	481	61	1,180	1,162
Rumania	----------	----------	123	1,675	1,636	450
Spain	44	18	592	621	2,222	2,393
Sweden	933	1,276	1,278	2,018	9,287	11,830
Switzerland	3.266	3,926	450	887	2,055	2,182
United Kingdom	12	238	3,758	33,986	11,564	15,167
Yugoslavia	44	----------	117	49	1,205	----------
Asia:						
India	----------	----------	436	822	335	1,903
Israel	1	----------	711	409	170	640
Turkey	----------	----------	26	599	244	3,578
Africa:						
Rhodesia, Zambia and Malawi	----------	----------	----------	246	2,773	4,359
South Africa, Republic of	----------	----------	73	222	1,519	2,327
United Arab Republic (Egypt)	----------	----------	881	9	665	55
Oceania: Australia	----------	----------	2,510	7,405	1,468	3,921
Other countries	90	140	638	1,512	6,171	3,794
Total	104,250	111,848	181,102	261,210	118,054	135,945

[1] This table incorporates some revisions.

TABLE 10.—Greece: Exports of magnesite and calcined magnesia, by countries

(Short tons)

Destination	Crude magnesite		Calcined magnesia	
	1963	1964	1963	1964
Canada	----------	----------	1,102	2,425
France	2,938	----------	3,570	1,919
Germany, West	260	645	22,875	31,568
Italy	12,983	15,192	----------	----------
Netherlands	2,784	2,650	28,354	31,321
Poland	606	471	----------	----------
United Kingdom	2,872	4,115	8,325	13,530
United States	----------	----------	29,359	15,922
Other countries	2	2	7,494	8,654
Total	22,445	23,075	101,079	105,339

Dalmia Magnesite Corp., Salem, Madras, the largest consumer of magnesite in India used about 200,000 short tons during 1963 for the production of dead-burned magnesite clinkers.

The price of crude magnesite ranged between \$6.67 and \$9.53 per short ton and that of calcined magnesite between \$35.40 and \$40.96 per ton f.o.b. Calcutta, India.

Italy.—Sarda Magnesite S.p. A. (Sardmag) and Palmas Cave S.p. A. announced construction of a plant to extract magnesium oxide from sea water at Sant'Antioco (Sardinia).

Mexico.—Quimica del Mar. S.A., formed by General Refractories Co. and a group of Mexican investors, announced plans to install a \$5 million plant in Mexico to produce magnesium oxide from sea water.

Netherlands.—Refractory magnesia exports in 1964 totaled 41,608 tons compared with 39,462 tons in 1963.

U.S.S.R.—A large magnesite deposit discovered in foothills of the East Sayans in the Soviet Union, was said to be suitable for all uses.[5]

TECHNOLOGY

New or improved extraction methods of magnesium compounds were studied or developed to expand recovery from various sources. While basic research was used in the study of the grain structure of magnesium, applied research on magnesium compounds was directed to meeting the demand for improved refractories.

The National Aeronautics and Space Administration awarded a contract to Kaiser Aluminum & Chemical Corp. to develop a specialized magnesium oxide refractory for use in storage heaters which supply air at 4,000° F for research on hypersonic aircraft.[6]

Magnesim oxide single crystals with the purity necessary for ceramic cores used in atomic furnaces were grown near Pittsburgh, Pa.

Extruded filaments, formed from magnesium oxide dispersed in a magnesium acetate-methanol-water system and then converted to thermally stable hollow fibers by heating or hydrolysis, was developed as a material for thermal insulation.[7]

The Steetley Magnesite Co., Ltd. of Hartlepool, England, developed a process to produce high-purity magnesia from sea water by pretreating the sea water in the main supply line with sulfuric acid, metered to maintain the pH at 3.8 to 4.0.[8] The acid reacted with the undesirable bicarbonates to form carbon dioxide which was removed in a desorption tower. With the addition of dolomitic lime, magnesium hydroxide was precipitated, filtered, and dead burned at 1,600° C.[9]

An article discussing the possibilities of recovering magnesium as magnesium chloride from naturally occurring brines and evaporites in conjunction with potash recovery was published.[10]

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[5] Chemical Trade Journal and Chemical Engineering (London). Large Magnesite Deposit Found in Siberia. V.155, No. 4045, 4046, Dec. 18, 1964, p. 851.

[6] American Ceramic Society Bulletin. Out of the Kiln. Magnesium Oxide. V. 43, No. 10, Oct. 7, 1964, p. 20a.

[7] Product Engineer. A New Material For Thermal Insulation. V. 35, No. 19, Sept. 14, 1964, p. 40.

[8] Chemical Trade Journal. Lime Removal from Sea Water Magnesia. V. 154, No. 4011, Apr. 24, 1964, p. 580.

[9] Chemical Trade Journal. Lime Removal from Sea Water Magnesia. V. 154, No. 4011, Apr. 24, 1964, p. 580.

[10] Nylander, A. F., and J. H. Jensen. Magnesium Chloride From Naturally Occurring Brines and Evaporites. J. Metals. V. 16, No. 9, September 1964, pp. 718–720.

A method of extracting mineral salts from lake and sea brines was patented. After the brine is subjected to solar evaporation and the sodium chloride is eliminated in accordance with conventional practice, the resulting complex brine is treated with calcium chloride solution to precipitate gypsum. The gypsum and hydrochloric acid are used as feed in an ion-exchange procedure which removes the sulfates regenerating calcium chloride and sulfuric acid. By appropriately treating the sulfate free brines; magnesium oxide, bromine, magnesium metal, and potassium chloride are produced. Potassium hydroxide, fertilizer, and additional hydrochloric acid are produced from potassium chloride.[11]

A process was patented to produce magnesium hydroxide and calcium chloride from a slurry of dolomite quicklime and brine containing magnesium chloride produced in a slaker fitted with a high speed stirrer.[12] The magnesium hydroxide is recovered by filtration and then washed. The calcium chloride remains in solution for either storage or futher treatment.

A liquid-gas contactor was developed and reported as an improvement for preparing magnesium bisulfite liquor used in the paper industry.[13] The high turbulent action in the contactor was reported to prevent slurry from clogging the system.

A foamed magnesium oxysulfate cement process and product was patented in which the product consisted essentially of from 25 to 40 weight-percent magnesium oxide, 11 to 15 percent magnesium sulfate, 0.15 to 1.5 percent a nonionic wetting agent, from 0.1 to 1 percent magnesium choride, and the balance water.[14]

A magnesium oxide slip casting method was patented whereby a scum inhibitor and hydrochloric acid, as a deflocculent, were added to a finely ground fused magnesia slurry which was immediately poured into a plaster mold for drying and firing.[15]

Lehigh University, Bethlehem, Pa., announced that its scientists discovered that the hydrophobic (water repelling) surface characteristic of silver iodide functions as the nucleating (cloud seeding) agent.[16] Silicas, clays, aluminas, bauxite, magnesite, magnesia, limestone, dolomite, lime, and other materials all have hydrophobic characteristics and can be investigated in connection with weather control.

An oxygen converter lining was patented consisting of a mixture of tar and dead-burned dolomite with or without dead-burned lime or magnesite analyzing 5–50 percent magnesia, and not over 4 percent combined total of silica, ion oxide, and alumina.[17]

Research was conducted on various ladle linings such as olivine bonded with sodium silicate; olivine and a proprietary material; ganister and fire clay; zirconite bonded with bentonite; silica sand bonded with sodium silicate; silica sand bonded with bentonite; backing sand; and chamotte (a calcined aluminus clay).[18]

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[11] Hadzeriga, Pablo. (assigned to Standard Magnesium Corp., Inc.), Recovery of Values from Natural Lake and Sea Brines. U.S. Pat. 3,099,528, July 30, 1963, 4 pp.

[12] Chemical Trade Journal and Chemical Engineer (London). Magnesium Hydroxide and Calcium Chloride. Morton Salt Co. British Pat. 955,931, v. 155, No. 4026, Aug. 7, 1964, p. 184.

[13] Chemical Engineering. Liquor-Making Eased for Magnesia-base Pulp Mills. July 20, 1964, pp. 80–81.

[14] Harrell, Bob R. (assigned to The Dow Chemical Co., Midland, Mich.). Foamed Magnesium Oxysulfate Cement and Process. U.S. Pat. 3,147,138, Sept. 1, 1964.

[15] Stoddard, Stephen D., and Donald E. Nuckolls (assigned to the U.S. Atomic Energy Commission). Magnesium Oxide Slip Casting Method. U.S. Pat. 3,116, 155, Dec. 31, 1963.

[16] American Metal Market. Alumina or Magnesia Seen as Material for Cloud Seeding. V. 72, No. 15, Jan. 22, 1964, p. 12, 14.

[17] Willenbrock, Jr., H. C. (assigned to Harbison-Walker Refractories Co.). Refractories, Ceramics and Heavy Clay Products. U.S. Pat. 3,148,238, Sept. 8, 1964, 4 pp.

The microstructure of magnesia grains in magnesites formed by burning crystalline and cryptocrystalline natural magnesites and in magnesites produced from sea water and brines by sintering magnesium hydroxide were studied, and the observations published.[19] The discussion included factors effecting periclase-periclase bonding, periclase-chromite bonding, reactions between periclase and chromite, and the influence of impurities and grain size on bonding.

Research disclosed that in rapidly cooled castings of certain fused periclase-spinel mixtures, the mechanism of segregation is similar to that which is operative in alloy systems.[20] High melting periclase is concentrated in the core of the casting and low melting spinel in the skin.

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[18] O'Brien, Edward W. Olivine Use for Small Shank Ladles. Modern Castings. V. 46, No. 2, August 1964, pp. 426-429.

[19] Treffner, Walter S. Microstructure of Periclase. J. Am. Ceram. Soc. V. 47, No. 8, August 1964, pp. 401-409.

[20] Ribbe, P. H., and A. M. Halper. Inverse Segregation of MgO and $MgAl_2O_4$ in Fusion-Cast Bodies. J. Am. Ceram. Soc. V. 47, No. 4, Apr. 21, 1964, pp. 162-167.

Manganese

By Gilbert L. DeHuff[1]

◆

DOMESTIC production of manganese ore—ore, concentrate, and nodules, containing 35 percent or more manganese—continued to be negligible in terms of consumption in 1964. On June 30, the President signed a bill suspending for 3 years the duty on manganese ore from countries other than those of the Sino-Soviet bloc. Imports of manganese ore for the year were at approximately the same level as those of the previous year, while ore consumption increased 22 percent.

TABLE 1.—Salient manganese statistics in the United States

	1955-59 (average)	1960	1961	1962	1963	1964
Manganese ore (35 percent or more Mn):						
Production (shipments):[1]						
Metallurgical..........short tons..	306,307	70,905	39,246	19,007	7,402	19,126
Battery....................do....	[2] 4,654	9,116	6,832	5,729	3,220	6,932
Miscellaneous...............do....	5	----------	10	22	----------	----------
Total[1]....................do....	310,966	80,021	46,088	24,758	10,622	26,058
Value.................thousands..	$23,909	$5,352	$3,224	(3)	(3)	(3)
Imports, general..........short tons..	2,454,465	2,543,841	2,098,438	1,970,152	2,093,473	2,064,990
Consumption..................do....	1,967,665	1,946,389	1,701,756	1,865,272	1,841,725	2,241,756
Manganiferous ore (5 to 35 percent Mn):						
Production (shipments)[1]..short tons..	689,723	658,455	225,004	338,501	543,125	238,776
Value..................thousands..	$4,242	$4,466	$1,480	(3)	(3)	(3)
Ferromanganese:						
Production..............short tons..	804,569	842,818	732,813	781,112	751,198	929,486
Imports for consumption........do....	143,479	120,222	221,936	126,716	148,630	212,629
Exports......................do....	2,757	751	469	4,114	678	3,903
Consumption..................do....	849,022	800,430	778,003	805,441	892,884	1,007,623

[1] Shipments are used as the measure of manganese production for compiling U.S. mineral-production value. They are taken at the point at which the material is considered to be in marketable form for the consumer.

[2] Battery ore included in metallurgical in 1958.

[3] Combined value for total manganese ore and total manganiferous ores equals $4,268,000 in 1962, $4,054,000 in 1963, and $3,024,000 in 1964.

LEGISLATION AND GOVERNMENT PROGRAMS

Effective July 1, 1964, the duty on manganese ore from countries other than the U.S.S.R. and certain other specified Communist countries, including mainland China, was suspended for 3 years by Public Law 88-338.

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[1] Commodity specialist, Division of Minerals.

In reply to an application made by members of the ferroalloy industry, the Office of Emergency Planning in July found that imports of manganese ferroalloys and electrolytic manganese metal at that time were not threatening to impair the national security.

In September, the U.S. Department of Agriculture invited U.S. firms to submit barter offers for approximately 170,000 tons of metallurgical-grade Brazilian ore to be exchanged for an equivalent value of wheat for export to Brazil. This was entirely apart from the barter agreement for which contracts were signed in 1963. Satisfactory bids were not received.

Earlier in the year, an invitation by General Services Administration for bids to purchase 240,000 short tons of low-grade manganese oxide and mixed manganese oxide-carbonate ores held at Butte, Mont., failed to produce acceptable bids.

TABLE 2.—Manganese materials in Government inventories as of December 31, 1964

(Thousand short tons, dry equivalent)

Type of Material	Total	National (strategic) stockpile	DPA inventory	CCC and supplemental stockpile
Stockpile grade:				
Battery:				
Natural ore	282	144	------	138
Synthetic dioxide	25	21	4	------
Chemical:				
Type A ore	147	29	------	118
Type B ore	101	2	------	99
Metallurgical ore	10,501	5,220	1,352	3,929
(Ferromanganese, standard high carbon)[1]	(979)	(143)	------	(836)
(Manganese metal, electrolytic)[1]	(12.8)	(1.7)	(5.3)	(5.8)
Nonstockpile grade:				
Battery ore, natural	5	------	------	5
Metallurgical ore	2,269	632	1,629	[2] 8

[1] Gross weight of upgraded forms of manganese. Equivalent ore quantities are included in the stockpile grade metallurgical ore figures.

[2] Includes ore equivalent of 584 short tons of nonstockpile grade high carbon ferromanganese.

DOMESTIC PRODUCTION

Taylor-Knapp Co., operating at Philipsburg, Mont., continued to be the only domestic producer of natural battery-grade ore. Oxide nodules of metallugical grade were produced in Montana from stocks of previously mined Montana carbonate ore. The only other production of manganese ore—ore, concentrates, or nodules, containing 35 percent or more manganese—was in New Mexico where ore was mined and shipped from the Black Canyon mine, Socorro County. The ore, although of metallurgical grade, was not used for metallurgical purposes.

Low-grade manganese ores (ferruginous manganese ores and middlings) containing 10 to 35 percent manganese were shipped from Minnesota, Montana, and New Mexico. In addition, manganiferous iron ore containing 5 to 10 percent manganese was shipped from Minnesota. All the Minnesota ore came from the Cuyuna range. Manganiferous zinc residuum was produced from New Jersey zinc ores.

TABLE 3.—Manganese and manganiferous ore shipped[1] in the United States, by States

(Short tons)

Type and State	1963		1964	
	Gross weight	Manganese content	Gross weight	Manganese content
Manganese ore (35 percent or more Mn, natural):[2]				
Montana	5,260	2,517	20,264	10,171
New Mexico	5,362	2,548	5,794	2,746
Total	10,622	5,065	26,058	12,917
Manganiferous ore:				
Ferruginous manganese ore (10 to 35 percent Mn, natural):				
Minnesota	347,336	42,307	157,429	19,485
Montana	1,688	548	3,638	1,058
New Mexico	41,144	4,814	46,657	5,412
Total	390,168	47,669	207,724	25,955
Manganiferous iron ore (5 to 10 percent Mn, natural):				
Michigan	152,957	9,223	----------	----------
Minnesota	----------	----------	31,052	3,006
Total	152,957	9,223	31,052	3,006
Total manganiferous ore	543,125	56,892	238,776	28,961
Total value manganese and manganiferous ore	$4,053,961	----------	$3,024,268	----------

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[1] Shipments are used as the measure of manganese production for compiling U.S. mineral production value. They are taken at the point at which the material is considered to be in marketable form for the consumer. Besides direct-shipping ore, they include, without duplication, concentrate and nodules made from domestic ores.

[2] All metallurgical except 6,932 short tons of battery ore (concentrate) containing 2,662 tons of manganese shipped from Montana in 1964, and 3,220 tons of battery ore (concentrate) containing 1,304 tons of manganese shipped from Montana in 1963.

CONSUMPTION, USES, AND STOCKS

Consumption of manganese ore increased substantially over that of 1963, but domestic contribution to the supply continued to be an insignificant portion of the total. However, 17 percent of the battery-grade ore consumed was of domestic origin. Industrial ore stocks were less than three-quarters of a year's supply at the 1964 consumption rate.

In the production of steel ingots, consumption of manganese as ferroalloys, metal, and direct-charged ore per short ton of open-hearth, bessemer, basic oxygen process, and electric steel produced was 13.8 pounds, compared with 13.9 pounds in 1963. Of the 13.8 pounds, 11.8 pounds was ferromanganese; 1.6 pounds, silicomanganese; 0.1 pound, spiegeleisen; and 0.3 pound, manganese metal.

Electrolytic Manganese and Manganese Metal.—Increases in consumption of manganese metal continued at an accelerated rate, with increases in virtually all of the end-use categories as summarized in table 5. Manganese metal used in the production of carbon steels increased by two-thirds, and there were appreciable gains in that used for stainless and other alloy steels. It can be assumed that, except for possibly a few pounds, all the manganese metal consumed, produced, and imported was electrolytic metal. American Potash & Chemical Corp., Hamilton (Aberdeen), Miss.; Foote Mineral Co., Knoxville, Tenn.; and Union Carbide Corp., Marietta, Ohio, continued to be the only domestic producers of manganese metal. Each company received a contract for production of electrolytic manganese metal for the Goverment in connection with the 1963 United States-Indian bilateral barter agreement. The aggregate quantity of the contracts was 10,000 short tons, and deliveries began in 1964.

Ferromanganese.—A strong demand for ferromanganese resulted in resumption of blast-furnace ferromanganese production at the Reusens (Lynchburg), Va., plant of E. J. Lavino & Co.; at Neville Island (Pittsburgh), Pa., by Shenango, Inc. (formerly Pittsburgh Coke & Chemical Co.); and at the Clairton, Pa., plant of United States Steel Corp. Electric-furnace production was resumed by The Anaconda Company at Anaconda, Mont., but no ferromanganese was among the products of Pittsburgh Metallurgical Co. at Niagara Falls, N.Y. In the last quarter of the year, the Roane electric furnace plant of Tennessee Products & Chemical Corp. at Rockwood, Tenn., was leased to Union Carbide Corp. with production continuing throughout the year. The quantity of ferromanganese made in blast furnaces was approximately twice that made in electric furnaces. Manganese Chemicals Corp. made low-carbon ferromanganese by fused salt electrolysis at Kingwood, W. Va. Shipments of ferromanganese totaled 942,000 tons valued at $135 million, compared with 802,000 tons valued at $125 million in 1963. Thirteen companies used 20 plants to produce ferromanganese in 1964.

Silicomanganese.—Production of silicomanganese in the United States was 203,000 short tons, compared with 152,000 tons in 1963. Shipments from furnaces totaled 214,000 tons ($30 million), compared with 155,000 tons ($24.9 million) in 1963. Seven companies produced silicomanganese in 11 plants. Except for Vanadium Corporation of America and the Sheffield, Ala., plant of Union Carbide Corp., producing plants were the same as in 1963 and 1962. Production at the Roane electric furnace plant of Tennessee Products & Chemical Corp., Rockwood, Tenn., was by that company in the first 9 months of the year and by Union Carbide Corp., as lessee, in the last 3 months. Consumption of silicomanganese relative to that of ferromanganese continued to increase: 17.4 percent in 1964, compared with 16.1 percent in 1963, 15.2 percent in 1962, 14.4 percent in 1961, and 12.3 percent in 1960.

Spiegeleisen.—The New Jersey Zinc Co., Palmerton, Pa., and Union Carbide Corp., Marietta, Ohio, produced spiegeleisen in electric furnaces; Shenango, Inc., used the blast furnace for its production.

Manganiferous Pig Iron.—In producing pig iron, furnaces used 457,000 short tons of manganese-bearing ores containing over 5 percent manganese (natural). Domestic sources supplied 339,000 tons and foreign sources supplied 118,000 tons. The domestic ore included 181,000 tons of manganiferous iron ore containing 5 to 10 percent manganese (natural) and 158,000 tons of ferruginous manganese ore containing 10 to 35 percent manganese. The foreign ore consisted of 99,000 tons of manganiferous iron ore containing 5 to 10 percent manganese (natural) and 19,000 tons of manganese ore containing 35 percent or more manganese. Canada supplied all the foreign manganiferous iron ore.

Battery and Miscellaneous Industries.—Manufacturers of dry-cell batteries used 30,000 tons of manganese ore containing more than 35 percent manganese (natural); 5,300 tons was of domestic origin.

TABLE 4.—Consumption and stocks of manganese ore[1] in the United States

(Short tons)

Use and ore source	Consumption 1963	Consumption 1964	Stocks Dec. 31, 1964[2] (including bonded warehouses)
Manganese alloys and manganese metal:			
Domestic ore	----------	10,371	342
Foreign ore	1,683,450	2,082,074	1,521,663
Total	1,683,450	2,092,445	1,522,005
Steel ingots: Foreign ore	793	725	43
Steel castings: Foreign ore	67	96	135
Pig iron: Foreign ore	34,830	18,706	19,516
Dry cells:			
Domestic ore	3,907	5,270	532
Foreign ore	23,963	24,844	9,694
Total	27,870	30,114	10,226
Chemicals and miscellaneous:			
Domestic ore	3,228	4,246	654
Foreign ore	91,487	95,424	45,453
Total	94,715	99,670	46,107
Grand total:			
Domestic ore	7,135	19,887	1,528
Foreign ore	1,834,590	2,221,869	1,596,504
Total	1,841,725	2,241,756	[3] 1,598,032

[1] Containing 35 percent or more manganese (natural).
[2] Excluding Government stocks.
[3] Excludes small tonnages of dealers' stocks.

TABLE 5.—Consumption, by end uses, and stocks of manganese ferroalloys and metal in the United States in 1964

(Short tons)

Use	Ferromanganese High carbon	Ferromanganese Medium and low carbon	Silicomanganese	Spiegeleisen	Manganese metal[1]	Briquets
Steel ingots:						
Stainless steel	689	4,097	7,816	138	8,920	----------
Other alloy steel	170,214	21,991	41,956	8,187	2,763	----------
Carbon steel	719,251	50,842	98,953	17,012	8,289	----------
Other	365	101	347	2	49	----------
Total	890,519	77,031	149,072	25,339	20,021	----------
Steel castings:						
Stainless steel	230	244	530	----------	106	----------
Other alloy steel	9,610	1,503	7,240	359	28	54
Carbon steel	6,971	1,180	12,150	979	18	172
Other	3,029	155	516	112	21	----------
Total	19,840	3,082	20,436	1,450	173	226
Steel mill rolls	1,695	256	774	924	----------	----------
Gray and malleable castings	5,857	993	3,865	9,641	1	11,688
Alloys (includes welding rods)	6,611	976	1,077	37	5,324	7
Other	691	72	----------	----------	215	----------
Grand total	925,213	82,410	175,224	37,391	25,734	11,921
Stocks, Dec. 31:[2]						
Consumer	98,364	9,459	16,483	4,402	3,216	1,145

[1] Virtually all electrolytic.
[2] Including bonded warehouses. Producer stocks of ferromanganese, silicomanganese, spiegeleisen, manganese metal, and briquets totaled 133,000 short tons. Excluding Government stocks

Chemicals and miscellaneous industries used 100,000 tons of manganese ore containing 35 percent or more manganese, of which 4,200 tons was of domestic origin. The domestic ore and much of the foreign ore did not meet National Stockpile Specification P–81–R for chemical-grade ore.

TABLE 6.—Ferromanganese produced in the United States and metalliferous materials[1] consumed in its manufacture

Year	Ferromanganese produced			Materials consumed			Manganese ore used per ton of ferromanganese [2] made (short tons)
	Gross weight (short tons)	Manganese content		Manganese ore (35 percent or more Mn natural)		Iron and manganiferous iron ores (short tons)	
		Percent	Short tons	Foreign (short tons)	Domestic (short tons)		
1955–59 (average)	804,569	77.2	621,001	[2] 1,704,184	[2] 38,616	1,481	2.2
1960	842,818	77.7	654,825	[2] 1,801,038	[2] 17,819	1,821	2.2
1961	732,813	77.3	566,432	[3] 1,577,519	[3] 9,446	1,685	2.1
1962	781,112	77.2	602,854	[2] 1,673,227	17,417	96	2.2
1963	751,198	77.2	579,852	[2] 1,617,112	------------	------------	2.2
1964	929,486	77.8	722,752	[3] 2,082,074	10,371	------------	2.2

[1] Excluding scrap and other secondary materials.
[2] Includes ore used in producing silicomanganese (in the 1955–59 period, for 1955 only).
[3] Includes ore used in producing silicomanganese and metal.

TABLE 7.—Manganese ore used in producing ferromanganese and silicomanganese in the United States, by source of ore

Source	1963		1964	
	Gross weight (short tons)	Mn content, natural (percent)	Gross weight (short tons)	Mn content, natural (percent)
Domestic	------------	------------	10,371	56.1
Foreign:				
Africa	755,936	46.1	872,356	47.4
Brazil	374,966	46.2	461,034	45.9
British Guiana	83,909	40.5	82,949	39.4
Chile	4,040	45.4	2,021	48.1
Cuba	16,709	38.9	21,635	38.9
India	161,931	45.4	288,828	44.2
Mexico	113,292	42.3	160,335	43.0
Philippines	10,201	39.8	991	46.4
Other or unidentified [1]	96,128	------------	191,925	------------
Total	1,617,112	45.3	2,092,445	45.8

[1] For 1964, includes ore used in producing metal.

PRICES

Manganese Ore.—All manganese ore prices are negotiated, being dependent in part on quality and quantity of ore offered, delivery terms, and fluctuations in shipping rates. American Metal Market quotations for metallurgical manganese ore containing 46 to 48 percent manganese, c.i.f. eastern seaboard and gulf ports, short-term deliveries, opened the year at 60 to 65 cents, nominal, per long ton unit of manganese, import duty extra. Following suspension of the import duty on June 30, this quotation by August 6 had incorporated the duty equivalent of 5.6 cents per long ton unit to arrive at 68 to 72 cents, nominal. This quotation remained unchanged to the end of the year, but some firming of actual prices was reported at yearend.

Manganese Alloys.—The average value at furnaces for ferromanganese shipped by domestic producers was $143.38 per short ton, compared with $155.93 in 1963. Prices for domestically produced standard high-carbon ferromanganese containing 74 to 76 percent manganese were weak and confused throughout most of 1964 with sales apparently not related entirely to published prices. The published schedule of one producer was unchanged throughout the year at $167.50 per long ton, f.o.b. furnaces, for carload lots of lump bulk material. In December, Bethlehem Steel Co. which had been selling "competitively" without a published schedule increased its price $10 per ton, and other producers announced increases to be effective January 1. Prices for imported alloy of the same grade were significantly lower than the domestic material in the first part of the year, but increased after mid-year so as to eliminate much of the differential. An increase of $3 in the price of speigeleisen containing 19 to 21 percent manganese, effective August 5, raised the price to $87 per long ton, f.o.b. Palmerton, Pa. This price remained unchanged to the end of the year.

Manganese Metal.—There were two price increases of 1 cent each for the standard grade of electrolytic manganese metal, one effective in July and the other on October 1. They brought the final prices for leading items in the last quarter to 30.75 cents per pound for carlots and 33.25 cents for ton lots packed in steel drums; 30 cents for carlots and 32.5 cents for ton lots of palletized or bulk shipments. The carlot price for palletized or bulk shipments is considered the index price for electrolytic manganese. The premium of 0.75 cent per pound for hydrogen-removed metal was maintained. The premium for the 5.5-plus percent nitrogen grade of metal was increased to 5.75 cents per pound. All prices were delivered prices.

FOREIGN TRADE

Imports.—The average grade of imported manganese ore increased somewhat to 47.5 percent manganese, having been 47.3 percent in both 1963 and 1962. Of the total ore received in 1964, Brazil supplied 26 percent and Gabon, 22 percent.

General imports of manganiferous ores containing more than 10 but less than 35 percent manganese totaled 1,292 tons, all of which came from Mexico. Of the imports for consumption of this grade, totaling 11,046 tons, 5,454 tons was from British Guiana; 4,230 tons from Brazil; 1,292 tons from Mexico; and 70 tons from Ghana.

Ferromanganese imports for consumption increased 43 percent due to shipments to the Government from India and Chile under previously executed barter agreements. Commercial imports were at approximately the same level as for 1963. Imports for consumption of silicomanganese totaled 10,841 tons and contained 6,869 tons of manganese. Norway supplied 6,053 tons; Republic of South Africa, 2,240 tons; Spain, 1,245 tons; Yugoslavia, 948 tons; and Japan 355 tons. Of total imports for consumption of 878 tons reported as manganese metal, 629 tons was from the Republic of South Africa, and 190 tons from Japan. The balance of 59 tons was reported to be from Canada,

TABLE 8.—U.S. imports of manganese ore (35 percent or more Mn), by countries

Country	General imports [1] (short tons)				Imports for consumption [2]					
					Short tons				Value	
	Gross weight		Mn content		Gross weight		Mn content			
	1963	1964	1963	1964	1963	1964	1963	1964	1963	1964
North America: Mexico	147,607	153,258	66,930	70,408	145,390	145,539	65,922	66,975	$4,278,712	$4,836,153
South America:										
Brazil [3]	875,576	545,734	412,190	260,770	929,419	703,238	438,421	333,359	28,487,662	18,613,338
British Guiana [4]	105,655	60,832	45,141	26,208	115,216	166,101	51,019	73,743	2,530,948	3,372,834
Chile	1,784	----------	749	----------	1,784	----------	749	----------	32,005	----------
Peru	4,025	962	1,767	467	8,400	1,532	3,593	715	139,766	25,165
Total	987,040	607,528	459,847	287,445	1,054,819	870,871	493,782	407,817	31,190,381	22,011,337
Europe:										
Greece	6,445	2,489	3,068	1,194	6,445	1,254	3,068	526	331,780	60,000
Netherlands	----------	28	----------	12	----------	28	----------	12	----------	1,807
Sweden	92	----------	46	----------	92	----------	46	----------	4,182	----------
Total	6,537	2,517	3,114	1,206	6,537	1,282	3,114	538	335,962	61,807
Asia:										
Goa [5]	2,369	----------	1,096	----------	----------	----------	----------	----------	----------	----------
India	169,267	219,791	77,314	100,311	232,992	468,584	106,175	211,758	5,239,105	11,174,601
Philippines	----------	3,920	----------	2,105	----------	3,920	----------	2,105	----------	86,000
Turkey	4,443	2,345	2,087	1,079	7,596	2,345	3,532	1,079	207,699	52,979
Total	176,079	226,056	80,497	103,495	240,588	474,849	109,707	214,942	5,446,804	11,313,580

Africa:										
Angola	45,752	21,436	22,118	10,959	52,813	43,643	25,703	22,194	1,393,418	1,236,474
British East Africa	------	------	------	------	345	------	195	------	15,302	------
Congo (Leopoldville)	234,044	171,359	117,296	84,784	246,755	322,989	122,723	163,821	7,299,495	7,965,059
Ethiopia	3,854	3,581	1,978	1,805	3,854	3,581	1,978	1,805	147,063	129,759
Gabon	(6)	[7] 212,884	(6)	[7] 105,666	(6)	[7] 209,458	(6)	[7] 104,391	(6)	[7] 4,659,637
Ghana	102,047	120,582	52,345	61,958	184,309	267,301	93,349	135,585	5,975,538	7,911,462
Ivory Coast	(8)	[9] 22,588	(8)	[9] 9,790	(8)	27,084	(8)	11,739	(8)	565,952
Morocco	38,221	43,097	20,097	21,561	40,906	69,534	21,621	36,339	1,943,327	3,157,404
Portuguese Western Africa, n.e.c	------	------	------	------	7,913	3,796	3,739	1,898	216,564	132,904
Rhodesia and Malawi	3,550	21,506	1,792	10,058	3,550	21,506	1,792	10,058	126,986	595,049
South Africa, Republic of	120,568	191,690	50,406	78,662	239,064	325,149	99,284	134,761	5,026,432	6,123,951
Western Africa, n.e.c. [10]	12,622	266,908	6,311	132,120	12,622	237,654	6,311	117,568	360,000	6,276,626
Western Equatorial Africa, n.e.c. [11]	215,552	------	108,253	------	150,055	------	74,889	------	3,649,534	------
Total	776,210	1,075,631	380,596	517,363	942,186	1,531,695	451,584	740,159	26,153,659	38,754,277
Grand total	2,093,473	2,064,990	990,984	979,917	2,389,520	3,024,236	1,124,109	1,430,431	67,405,518	76,977,154

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[1] Comprises ore received in the United States; part went into consumption during the year, and the remainder entered bonded warehouses.
[2] Comprises ore received during the year for immediate consumption and material withdrawn from bonded warehouses.
[3] Data adjusted by Bureau of Mines to include material reported by the Bureau of the Census from Uruguay.
[4] Data adjusted by Bureau of Mines to include material reported by the Bureau of the Census from Trinidad and Tobago.
[5] Reported by Bureau of the Census as Southern and Southeastern Asia, n.e.c.; believed to be Goa by the Bureau of Mines.
[6] Reported as Western Equatorial Africa, n.e.c.
[7] In addition, 238,000 tons (gross weight) reported as Western Africa, n.e.c., is believed to have been from Gabon.
[8] Reported as Western Africa, n.e.c.
[9] In addition, 29,000 tons (gross weight) reported as Western Africa, n.e.c., is believed to have been from Ivory Coast.
[10] In 1963, believed to be all from Ivory Coast; 1964, known to be from both Gabon and Ivory Coast.
[11] Believed to be all from Gabon.

Source: Bureau of the Census.

TABLE 9.—U.S. imports for consumption of ferromanganese, by countries

Country	1963			1964		
	Gross weight (short tons)	Mn content (short tons)	Value	Gross weight (short tons)	Mn content (short tons)	Value
North America:						
Canada				3,254	2,503	$377,911
Mexico	1,420	1,094	$146,476			
Total	1,420	1,094	146,476	3,254	2,503	377,911
South America: Chile	8,571	6,491	1,257,584	5,815	4,374	782,300
Europe:						
Belgium-Luxembourg	8,882	6,764	1,020,077	32,763	25,067	3,189,193
France	42,595	32,791	5,030,875	39,360	30,162	4,143,601
Germany, West	47,866	36,724	4,767,124	21,731	16,528	2,328,689
Italy	440	353	82,000	1,600	1,284	299,728
Netherlands				616	467	59,843
Spain	6,834	5,307	672,800	9,584	7,385	841,615
Yugoslavia	220	173	21,796			
Total	106,837	82,112	11,594,672	105,654	80,893	10,862,669
Asia:						
India	2,883	2,196	278,298	74,551	56,000	10,941,727
Japan	8,987	7,263	1,631,828	5,123	4,160	999,033
Total	11,870	9,459	1,910,126	79,674	60,160	11,940,760
Africa:						
Mozambique	1,120	840	107,850			
South Africa, Republic of	18,812	15,381	1,957,032	18,232	14,145	1,847,480
Total	19,932	16,221	2,064,882	18,232	14,145	1,847,480
Grand total	148,630	115,377	16,973,740	212,629	162,075	25,811,120

Source: Bureau of the Census.

but its declared value of $2,206 was too low for manganese metal. In addition, 8 pounds of metal were imported from Italy valued at $1,048. Speigeleisen imports for consumption were 560 tons, all from West Germany.

Exports.—Ferromanganese exports totaled 3,903 tons valued at $670,000, compared with 678 tons valued at $155,000 in 1963, and 4,114 tons valued at $629,000 in 1962. This export classification included silicomanganese. Exports classified as "manganese metal and alloys in crude form and scrap," believed to be almost entirely electrolytic manganese metal, were 3,284 tons valued at $1,833,000, compared with 2,062 tons valued at $1,229,000 in 1963, and 2,201 tons valued at $1,431,000 in 1962. Spiegeleisen exports in 1964 were 785 tons valued at $59,000. Canada received 763 tons and Australia 22 tons. Exports classified as "manganese ore and concentrates containing 10 percent or more manganese" totaled 14,444 tons valued at $1,451,000. They were believed to consist almost entirely of imported manganese dioxide ore exported after grinding, blending, or otherwise classifying.

Tariff.—The duty on manganese ore of 0.25 cent per pound of contained manganese, applicable to most countries, was suspended for 3 years beginning July 1, 1964. This left ore from the U.S.S.R., mainland China, and certain other specified Communist countries as the only manganese ore still dutiable, the rate remaining at 1 cent per pound of contained manganese.

WORLD REVIEW

NORTH AMERICA

Mexico.—Mining at the San Francisco mine of Cia. Minera Autlan at Autlan, Jalisco, was at the rate of 1,000 tons of manganese ore per day on a 2-shift basis. Heavyduty steel friction props were used to support the roof while using a longwall retreat system for mining the nearly flat-lying bed of ore.[2] The company, in which Bethlehem Steel Co. had an interest, announced at the end of 1964 that the mine would be shut down over a period of 2 years.

TABLE 10.—World production of manganese ore by countries [1] [2]

(Short tons)

Country [1]	Percent Mn [e]	1955–59 (average)	1960	1961	1962	1963	1964 [p]
North America:							
Costa Rica (exports)	35+	-------	-------	-------	-------	661	-------
Cuba	36–50+	[3] 169,623	[4] 17,644	[e] [3] 46,000	[e] 83,000	[e] 83,400	[e] 83,400
Mexica [e]	44–46	171,600	171,400	155,900	184,900	189,300	206,500
Panama	-------	[5] 1,328	-------	-------	-------	-------	-------
United States (shipments)	35+	310,966	80,021	46,088	24,758	10,622	26,058
Total [e]	-------	653,517	269,100	248,000	292,700	284,000	316,000
South America:							
Argentina	30–40	14,554	24,251	19,724	13,921	[e] 16,500	20,650
Bolivia (exports)		-------	-------	53	291	-------	-------
Brazil	38–50	739,978	1,101,387	1,120,336	1,290,461	1,382,727	1,191,206
British Guiana	40–42	-------	137,454	237,582	303,636	157,331	130,907
Chile	40–50	49,013	50,594	35,012	47,578	51,234	22,450
Peru	40+	8,649	1,655	3,879	7,403	457	485
Venezuela	38+	[6] 11,134	-------	-------	-------	-------	-------
Total	-------	823,328	1,315,341	1,416,586	1,663,290	1,608,249	1,365,698
Europe:							
Bulgaria	30+	60,646	27,558	40,785	38,581	42,432	57,320
Greece	35+	22,803	34,410	31,195	15,097	16,389	[e] 33,100
Hungary	30–	156,185	135,888	137,610	142,447	167,960	[e] 143,300
Italy	30–	54,493	54,561	54,196	49,053	49,920	52,672
Portugal	35+	5,423	8,197	12,492	12,666	9,434	7,587
Rumania	35	283,786	192,872	227,076	208,337	286,601	[e] 275,600
Spain	30+	43,057	24,586	17,092	14,101	16,858	17,559
U.S.S.R. [7]	-------	5,668,000	6,473,000	6,583,000	7,057,000	7,345,000	[e] 7,385,000
Yugoslavia	30+	6,949	14,676	15,595	16,357	8,964	8,580
Total [1]	-------	6,301,342	6,965,748	7,119,041	7,553,639	7,943,558	[e] 7,981,000
Asia:							
Burma	42+	828	324	196	213	[e] 220	-------
China [e]	30+	739,000	1,323,000	882,000	882,000	1,102,000	1,102,000
Goa	32–50	140,864	118,195	109,790	96,732	[3] 115,290	1,392,218
India	35+	1,655,503	1,321,411	1,355,868	1,351,432	1,184,983	
Indonesia	35–49	63,468	12,026	14,007	5,460	1,903	[e] 550
Iran [8]	40+	3,478	8,488	2,315	2,205	[e] 1,100	[e] 2,200
Japan	32–40	312,998	357,131	335,236	340,162	305,028	311,928
Korea, South	30–48	2,062	1,521	1,518	1,105	4,580	4,753
Malaysia	30+	-------	3,222	7,130	341	7,696	-------
Pakistan	42+	[9] 32	327	-------	1,036	1,553	1,098
Philippines	35–51	22,855	19,159	20,986	13,160	8,450	8,824
Thailand	40+	[6] 477	582	588	3,194	7,285	12,185
Turkey	30–50	49,796	31,112	33,951	23,422	6,949	22,366
Total [e]	-------	2,991,000	3,196,000	2,764,000	2,720,000	2,747,000	2,858,000

See footnotes at end of table.

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[2] Lipensky, Milan. Longwall Mining in Hardrock. Min. Eng., v. 16, No. 12, Dec. 1964, pp. 53–56.

TABLE 10.—World production of manganese ore by countries[1] [2]—Continued

Country [1]	Percent Mn [e]	1955–59 (average)	1960	1961	1962	1963	1964 [p]
Africa:							
Angola	38–48	32,373	25,728	22,695	9,115	-------	-------
Bechuanaland	30+	[5] 11,531	25,032	31,737	26,458	11,878	27,116
Congo, Republic of the (Leopoldville)	48+	415,046	420,671	348,595	348,547	297,660	341,385
Ethiopia (shipments)	51	[9] 1,455	10,202	7,716	6,614	-------	-------
Gabon	50–52	-------	-------	-------	224,038	712,381	1,045,324
Ghana (exports)[10]	48	635,345	600,261	431,282	513,622	434,410	545,068
Ivory Coast	38+	-------	80,748	137,825	117,928	153,291	150,383
Morocco	35–50	486,159	532,508	629,512	517,377	369,217	375,974
Rhodesia (formerly Southern)	30+	1,714	1,676	205	7,977	-------	160
South Africa, Republic of	30+	841,808	1,316,132	1,562,729	1,614,599	1,441,503	1,455,271
South-West Africa	45+	68,258	67,439	50,295	-------	-------	-------
Sudan	36–44	[e] [6] 5,890	-------	-------	1,120	-------	-------
United Arab Republic (Egypt)[11]	35+	27,570	22,046	2,272	42,577	23,798	[e] 47,000
Zambia	30+	41,972	59,299	58,517	51,501	38,856	41,899
Total [1]	-------	2,569,121	3,161,742	3,283,380	3,481,473	3,482,994	4,029,580
Oceania:							
Australia	45–48	74,663	67,923	97,901	80,244	40,548	69,048
Fiji	40+	23,759	13,073	3,869	1,202	3,621	1,004
New Hebrides	52–55	-------	-------	5,060	21,859	28,016	66,740
New Zealand	48+	125	134	-------	-------	-------	-------
Papua	46	8	54	2	-------	4	3
Total	-------	98,555	81,184	106,832	103,305	72,189	136,795
World total (estimate)[1]	-------	13,437,000	14,989,000	14,938,000	15,814,000	16,138,000	16,687,000

[e] Estimate. [p] Preliminary.

[1] Czechoslovakia and Sweden report prodution of manganese ore (approximately 13 to 17 percent manganese content), but since the manganese content averages substantially less than 30 percent, the output is not included in this table. Czechoslovakia averages annually 110,000 short tons and Sweden approximately 11,000 tons for the last 5 years. Malagasy produces a negligible amount of manganese.

[2] This table incorporates some revisions. Data do not add exactly to totals shown because of rounding where estimated figures are included in the detail.

[3] Exports.

[4] United States imports.

[5] Average annual production 1957–59.

[6] Average annual production 1956–59.

[7] Grade unstated. Source: The Industry of the U.S.S.R., Central Statistical Administration (Moscow).

[8] Year ending March 20 of year following that stated.

[9] One year only as 1959 was the first year of commercial production.

[10] Dry weight.

[11] In addition to high-grade ore shown in the table, Egypt produced the following tonnages of less than 30 percent manganese content: 1955–59 (average), 131,626; 1960, 282,191; 1961, 304,663; 1962, 162,102; 1963, 160,673.

SOUTH AMERICA

Chile.—The manganese ore produced in 1963 averaged 45.5 percent manganese. Of the total, approximately 4 percent was purchased by the State-owned Empresa Nacional de Mineriá from small operators in Coquimbo and Antofagasta provinces. The remainder was divided almost equally between Cia. Manganesos Atacama's mine in the Corral Quemado district of Coquimbo province and Cia. Manganesos Chile. Most of the ore was used to make ferromanganese for export to the United States under agricultural barter contract.[3] Detailed study of the manganese mining districts of Coquimbo province by the Instituto de Investigaciones Geológicas was reported. Manganese deposition occurs in at least three different stratigraphic horizons of early Cretaceous age. In order of abundance, the manganese minerals are braunite, pyrolusite, manganite, psilomelane, and hausmannite.[4]

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[3] Bureau of Mines. Mineral Trade Notes. V. 59, No. 2, August 1964, p. 35.

EUROPE

Germany, West.—Phoenix-Rheinrohr increased the price of standard ferromanganese approximately 4 percent, effective October 1. This was apparently the first European price rise of the year for this alloy.[5]

Greece.—A Greek-Yugoslav trade agreement signed December 22, 1964, provides that Greece export to Yugoslavia 10,000 tons of manganese ore in the year beginning October 1, 1964.[6] A large concentration of manganese-iron nodules was reported to have been discovered by a Soviet oceanographic ship on the floor of the Aegean Sea off the south coast of the island of Santorini (Thera).[7]

Hungary.—Both manganese carbonate and manganese oxide ores occur at Urkut. Previously, the carbonate ore has been considered of no value, but a promising procedure has been developed wherein the manganese carbonate is dissolved by acid in the presence of a small quantity of oxide ore.

Italy.—All the low-grade manganese ore produced in 1964 from the Gambatesa mines of Ferromin near Lavagnia, east of Genoa, was shipped by rail to the Darfo works of Italsider in Brescia.[8]

Netherlands.—By September 1964, the new plant of AIME-Lavino N.V. was on stream producing manganese compounds at the annual rate of about 1,000 tons. Plans called for later doubling capacity.[9] Chief product was manganous oxide for use in animal and poultry feeds and in fertilizers.

Spain.—Manganese ore produced in 1964 had an average manganese content of 32.2 percent. Production of ferromanganese was 41,000 tons.

Sweden.—Manganiferous ore produced in 1962, 3,600 tons, had an average manganese content of 17.5 percent.

U.S.S.R.—Soviet electrolytic manganese metal offered for sale in the United Kingdom in 1964 had a manganese content of 99.7 percent or better.[10] A plant was being designed for production of several thousand tons per year of an organo-manganese antiknock compound for gasoline.[11] In the Chiatura district, two new mines, one at Meryev and the other at Zedargah, were in operation in early 1964. Pravda reported that they will supply "hundreds of thousands of tons of manganese ore annually." [12] Another new mine in the Chiatura district, the fourth since 1959, was scheduled to go into full-scale operation sometime after midyear.[13] Chiatura annually produces roughly

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[4] Aguirre, Luis, and Sonia Mehech. Stratigraphy and Mineralogy of the Manganese Sedimentary Deposits of Coquimbo Province, Chile. Econ. Geol., v. 59, No. 3, May 1964, pp. 428–442.

[5] Metal Bulletin (London). No. 4935, Oct. 2, 1964, p. 15.

[6] Mining Journal (London). V. 264, No. 6752, Jan. 15, 1965, p. 47.

[7] Mining Journal (London). V. 262, No. 6720, June 5, 1964, p. 449.

[8] Metal Bulletin (London). No. 4968, Jan. 29, 1965, p. 21.

[9] Chemical Trade Journal and Chemical Engineer (London). V. 155, No. 4038, Oct. 30, 1964, p. 593.
European Chemical News (London). V. 6, No. 140, Sept. 18, 1964, p. 22.

[10] Metal Bulletin (London). No. 4951, Nov. 27, 1964, p. 20.

[11] Chemical Trade Journal and Chemical Engineer (London). V. 155, No. 4034, Oct. 2, 1964, p. 462.

[12] Metal Bulletin (London). No. 4870, Feb. 7, 1964, p. 25.

[13] Mining Journal (London). V. 263, No. 6728, July 31, 1964, p. 79.

2 million[14] tons of manganese concentrate of various grades. The nearly flat-lying ore is mined underground by room and pillar or long wall methods from adits driven from the walls of steep-sided gorges. Aerial tramways serve many of the mines for delivering ore to the concentrators, of which there are at least eight in the district. One of these, Davodoshnaya, was built in 1962 as a central mill for treating the middling products of the other mills. It employs both flotation and wet, high-intensity magnetic separation in producing several grades of concentrate.

United Kingdom.—The new plant of Berk-Leiner Ltd. at Treforest, near Pontypridd, South Wales, started operating in July at an initial annual production rate of 500 tons of electrolytic manganese dioxide. Eventual output is expected to be 1,000 tons per year.[15] Japanese and U.S.S.R. electrolytic manganese metal, used in the United Kingdom largely for production of nonferrous alloys, was offered at prices competitive with those for South African metal.[16]

Yugoslavia.—In the first part of 1964, ferromanganese was produced only by the Ferrous Alloy Factory (Fabrika ferolegura) in Sibenik. Feed material consisted of a blend of good imported ore with poor domestic ores from the Cer and Cevljanovici mines, with the imported ore contributing 75 percent of the requirements. A process was developed at Trepca on a semi-industrial scale for obtaining a manganese concentrate, suitable for production of ferromanganese, from low-grade domestic ores and waste materials. The reserve of low-grade ore in the Trepca region was estimated at 1.8 million tons having a manganese content of 12.6 percent. A new manganese mining operation at Nova Brdo in Kosmet was experiencing technical difficulties in getting into production.

ASIA

China.—Manganese ore was among the minerals and metals imported by the United Kingdom from China in both 1963 and 1964.[17]

India.—A license for manufacturing 1,800 tons each of electrolytic manganese metal and manganese dioxide was granted to Devidayal (Sales) Private Ltd., Bombay. It was planned to use low-grade ore under the guidance of the National Metallurgical Laboratory, developers of the process.[18] Although the State-owned Minerals and Metals Trading Corp. (MMTC) had barter arrangements in 1964 with the United Kingdom, Japan, and Switzerland, as well as the United States,[19] it was decided by midyear that no new barter agreements would be made. This change in policy was influenced by the improved market and the fact that European buyers were interested in long-term contracts that are not possible under the barter system.[20] MMTC shipped 80 percent of the manganese ore exported in 1964.[21] By the end of the year, with only 30 or 40 mines reported to be operating, there was a shortage of the higher grades of ore. No more private barter contracts were to be permitted after year-end.

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[14] Northern Miner (Toronto, Canada). V. 50, Nos. 28 and 29, Oct. 1 and 8, 1964, p. 19.
[15] Metal Bulletin (London). No. 4933, Sept. 25, 1964, p. 13.
[16] Metal Bulletin (London). No. 4951, Nov. 27, 1964, p. 20.
[17] Mining Journal (London). V. 263, No. 6739, Oct. 16, 1964, p. 287.
[18] Mining Journal (London). V. 262, No. 6701, Jan. 24, 1964, p. 70.
[19] E&MJ Metal and Mineral Markets. V. 35, No. 16, Apr. 20, 1964, p. 3.
[20] Mining Journal (London). V. 263, No. 6725, July 10, 1964, p. 25.
[21] Metal Bulletin (London). No. 4977, Mar. 2 ,1965, p. 18.

Of the manganese ore produced in 1963, 33 percent was mined in Orissa, 22 percent each in Mysore and Madhya Pradesh, 13 percent in Maharashtra, 5 percent in Andhra Pradesh, and the remainder in Gujarat and Bihar. Exports of 1,016,000 tons comprised 85 percent of production. Of the total exports 21 percent contained 48 percent or more manganese; 47 percent, between 35 and 48 percent manganese; 30 percent, less than 35 percent manganese; and 14,000 tons were classified as peroxide and other. Japan was the largest receiver, with 40 percent, and the United States was second with 12 percent. Ferromanganese production in 1963 was 142,000 tons, or 75 percent of capacity. Ferro Alloys Corp., Ltd., Garividi, Andhra Pradesh; Khandelwal Ferro-Alloys Ltd., Kamptee, Maharashtra; Tata Iron and Steel Co., Joda, Orissa; Jeypore Sugar Co., Rayagada, Orissa; Universal Ferro and Allied Chemicals Ltd. (formerly Cambatta Ferromanganese Ltd.), Tumsar, Maharashtra; and Electro Metallurgical Works, Dandeli, Marharashtra, were the producers in the order of size of contribution to the total. Only 4,600 tons was exported, of which North Korea took 74 percent and the United Kingdom and South Korea virtually all of the remainder. Local consumption was estimated to have been 55,000 tons.[22]

Indonesia.—In 1963 The Manganese Mining Co., capable of annually producing 9,000 to 12,000 tons of manganese ore at Kliripan in Central Java, was expropriated by the Special District of Jogjakarta.[23] In 1964, only one of Indonesia's four manganese mining facilities was operating.

Japan.—A new low-cost process for electric furnace production of high carbon ferromanganese, involving preheating with furnace gases, was developed by Awamura Mining Co. Kawasaki Steel Co. will join with Awamura and three other companies in building a plant at Mizushima, which initially will have one 6,000 kilovolt-amperes furnace capable of producing 15,000 tons per year.[24] The three principal producers of electrolytic manganese dioxide, Mitsui Kinzoku Kogyo, Tekkosha Co., and Hanshin Yosetsu Kizai, were increasing capacity so that the Japanese total would be approximately 27,000 tons per year in 1965.[25] In 1963, production was 11,401 tons. Exports were 8,455 tons to various countries, but with none to the United States. Production and exports of electrolytic manganese metal in the same year were 5,596 tons and 2,757 tons, respectively. Metallurgical manganese ore produced in 1962 and 1963 averaged 33.2 and 33.0 percent manganese, respectively. Production was from 141 mines, of which about five supplied half of the total. Three of these five mines were in Hokkaido. Domestic production satisfied only half the Japanese requirement. Approximately 12,000 tons of manganese dioxide ore also was produced in each of the years 1962 and 1963, for use in dry cell batteries, photographic materials, and zinc refining.[26]

Philippines.—Battery-grade manganese ore was reported to have been produced for local consumption by Philippine Manganese, Inc., in the first and second quarters of 1964, respectively 397 and 266 tons. Acoje Mining Co., Inc., in the third quarter started producing and exporting metallurgical ore from its Sierra Madre deposit on Luzon Island, 15 miles inland from the Philippine Sea at the junction of Isabela and Quezon provinces. The proven reserve was 223,000 tons averaging 44 percent manganese and 6 percent iron. Acoje was the only manganese ore producer in the final half of the year; exports went to Japan.

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[22] Bureau of Mines. Mineral Trade Notes. V. 60, No. 1, January 1965, pp. 14–15.
[23] Bureau of Mines. Mineral Trade Notes. V. 59, No. 5, November 1964, pp. 45–46.
[24] Metal Bulletin (London). No. 4898, May 22, 1964, p. 23; No. 4934, Sept. 29, 1964, p. 11.
[25] European Chemical News (London). V. 6, No. 143, Oct. 9, 1964, p. 6.
[26] Bureau of Mines. Mineral Trade Notes. V. 60, No. 2, February 1965, p. 27.

Thailand.—Manganese exports doubled in 1963 and included metallurgical as well as battery-grade ore.

AFRICA

Bechuanaland.—Deposits of battery-grade manganese ore being mined in Transvaal extend across the border into the Lobatsi Block of Bechuanaland. Marble Lime & Associated Industries, Ltd., prospected the area and a contract to supply Eveready of South Africa was a possibility. The Ootse mine continued to operate in the Bamalete Tribal Territory. The ore is suitable for metallurgical purposes and for use in the uranium mills of South Africa; some was exported to the United States.[27]

Congo, Republic of the (Leopoldville).—Société Miniere de Kisenge interests announced that Société Afripile would be formed to produce 20 million high quality dry-cell batteries per year at Kisenge.

Ghana.—Exports of manganese ore in 1964 consisted of 15,300 tons of battery grade, 530,000 tons of metallurgical grade, and 12,700 tons containing less than 30 percent manganese.

Ivory Coast.—The open pits at the Grand Lahou manganese ore deposits of Cie. Mokta el Hadid were operated with portable compressors, ½- and ¾-yard diesel shovels, bulldozers with rippers, and 3-cubic yard trucks. Ore from several pits was sent to a washer having a capacity of 400 tons per hour.[28] In 1964, three products were obtained: A concentrate averaging approximately 46 percent manganese; a lower grade concentrate or middling of 40 percent manganese content; and fines which averaged 38 percent manganese. Only the 46 percent and 38 percent products were exported, but with development of new markets for both of the lower grades, primarily in the United States, a 25 to 50 percent increase in exports was expected. The known reserve of these deposits was estimated in 1964 to be 600,000 tons of ore at 46 percent manganese plus 150,000 tons of fines at 38 percent.

Morocco.—Export statistics showed the United States taking three-quarters of the chemical ore in 1962 and almost half in 1963. France received the greater part of the metallurgical ore in both years, and all of the sinter except for shipments to the United States of 20,000 tons in 1962 and 6,400 tons in 1963. Of the manganese ore produced in 1963, 20 percent was chemical grade.[29] The Imini mine (Ste. Ch. d'Etudes Min.) produced 92 percent of the chemical ore, and the remainder was mined by small independent operators. That from Imini averaged 82 percent manganese dioxide; the other was of lower grade down to 60 percent. Sinter in the amount of 98,000 tons was produced from 124,000 tons of ore, mostly by Société Anonyme Chérifienne d'Etudes Minières (SACEM) at its Sidi Marouf (Casablanca) plant, but a small quantity was produced by Société des Mines de Bou Arfa at Bou Arfa. Metallurgical ore from the Imini averaged 48 percent manganese; the almost equal quantity from the Hamarouet and Falet mines of Ste. de Bou Arfa ran 30 to 35 percent manganese. The entire concession of SACEM has been explored and its ore reserves, apparently essentially those of the Imini mine, are estimated at 3 million tons. Production at Imini is expected to be maintained at approximately 160,000 tons annually with selective mining emphasizing production of chemical ore. In June a new pilot plant at Timkit was expected to start testing a new plastic shaking table to recover fines less than 1.5 millimeters. It was considered possible that this could increase production of chemical-grade ore by as much as 25 percent.

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[27] Bureau of Mines. Mineral Trade Notes. V. 60, No. 3, March 1965, p. 31.

[28] World Mining. V. 18, No. 3, March 1965, p. 75.

[29] Bureau of Mines. Mineral Trade Notes. V. 59, No. 3, September 1964, pp. 39–40.

South Africa, Republic of.—An expansion program for Electrolytic Metal Corp. (Pty.) Ltd. was planned to increase productive capacity for electrolytic manganese metal 50 percent to 8,400 short tons per year in a first stage to be ready by October 1965. Further expansion to 11,000 tons by 1967 was considered probable. Manganese sulfate monohydrate and manganese carbonate will be other products.[30] A deposit of battery-grade ore discovered at Maloney's Eye, near Johannesburg, was estimated to contain 1 million tons of ore. The Orient Manganese Co. was mining manganese ore at the same farm.[31] General Manganese Products (Pty.) Ltd. was unable to produce battery grade manganese dioxide economically at its plant at Krugersdorp and suspended the operation.

The two new furnaces at the Cato Ridge plant of Ferroalloys Ltd. were commissioned in early 1964. The Mamatwan mine of South African Manganese, Ltd., went into production in November 1963 with African Metals Corp. (AMCOR) taking its shipments. High iron content of the ore at the Hotazel mine continued to present problems, and difficulties were experienced in obtaining sufficient railway trucks for the corporation's ore shipments. Most of the local sales of South African Manganese, Ltd., were to AMCOR and to the government-owned Iron and Steel Corp., Ltd. (ISCOR). The Lohathla section provided ore for both export and domestic consumption, and operations on the eastern belt of the Postmasburg field continued for specific local markets.

OCEANIA

Australia.—Broken Hill Pty. Co., Ltd., was granted 13 square miles of mineral leases on Groote Eylandt, in the Gulf of Carpentaria, and a part of the Arnhem Land aboriginal reserve. The company planned to develop a manganese deposit, including construction of port and town, for open pit mining within 2 years at a rate of 70,000 tons per year.[32] The deposit will be mined by a newly formed subsidiary, Groote Eylandt Mining Co., Pty., and the ore shipped to the Bell

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[30] Metal Bulletin (London). No. 4966, Jan. 22, 1965, p. 19.
[31] Metal Industry (London). V. 104, No. 16, Apr. 16, 1964, p. 524.
[32] Metal Industry (London). V. 105, No. 6, Aug. 6, 1964, p. 184.
Mining Journal (London). V. 263. No. 6729, Aug. 7, 1964, pp. 98–99.

Bay, Tasmania, plant of another subsidiary, Tasmanian Electro-Metallurgical Co. Pty., Ltd. (TEMCO)[33] where productive capacity of standard high carbon ferromanganese will be doubled by the end of 1965 to 72,000 tons per year by the addition of a second 13,000 kilovolt-amperes rotating Elektrokemisk furnace.[34] Temco's annual consumption of manganese ore will then be 100,000 tons. Australia's 1964 production of manganese ore was all in the Pilbara district of Western Australia, and the greater part of the metallurgical ore produced was exported to Japan. Broken Hill also produced ferromanganese and silicomanganese at its own ferroalloy plant at its Newcastle, New South Wales, steel works.[35]

TECHNOLOGY

Following additional investigation, the Bureau of Mines raised its estimate of the inferred resource of manganiferous material in the Batesville district of Arkansas to 222 million short tons, and dropped the average grade to approximately 4 percent manganese. The manganiferous limestone portion of the resource was estimated to be 196 million tons with an average grade of 4 percent manganese. Manganiferous clay constituted most of the remainder.[36]

Results of an evaluation study for mining and treating the hard ore (10 percent manganese) from the Maggie Canyon block of the Artillery Mountains deposit of Arizona were reported by the Bureau. Two applicable alternative methods of treatment were investigated: One employing oil-emulsion flotation; the other, leaching with dithionate solutions. Although the dithionate process would recover more manganese from the deposit, the cost per ton of ferromanganese was noticeably higher. Neither process was considered economical.[37]

After melting a rhodonite concentrate from Silverton, Colo. (containing 28.8 percent manganese) and quenching with water, a quenched material was obtained having a manganese content of 34 percent. Leaching this with sulfuric acid in mechanically agitated cells recovered more than 90 percent of its manganese in a solution having a manganese concentration of 100 grams per liter. The batch studies indicated that manganese can be extracted from the melted and quenched concentrate without undue technical difficulty, either with sulfuric acid or with sulfur dioxide under acid-making conditions. Time of leaching and other considerations favored use of the sulfuric acid. Preliminary studies indicated that manganese metal can be electrodeposited from the leach liquor in a normal manner, and the spent electrolyte can be used for leaching.[38]

In laboratory-scale leaching tests using a pickle liquor (ferrous sulfate-sulfuric acid solution) waste from a steel mill, or a synthetic pickle liquor of similar composition, extractions of 77 to 84 percent of the manganese contained in Georga umber (5 percent manganese and 44 percent iron) were obtained. Leaching temperatures varied from 7° to 101° C. A 78-percent extraction was achieved in a leaching time of 15 minutes. Autoclaving with heat, using a simulated pickle liquor containing 562 pounds of ferrous sulfate and 250 pounds of sulfuric acid per ton of ore, increased manganese extractions to as much as 94 percent. The resulting filtrate contained some unreacted ferrous sulfate but little ferric iron.[39]

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[33] Metal Bulletin (London). No. 4954, Dec. 8, 1964, p. 18.

[34] Bureau of Mines. Mineral Trade Notes. V. 60, No. 1, January 1965, p. 14.

[35] Metal Bulletin (London). No. 4919, Aug. 7, 1964, p. 26; No. 4961, Jan. 5, 1965, p. 16.

[36] Stroud, R. B. Manganese Resources of the Batesville District, Arkansas (In Three Parts). 3. Field Investigations: July 1956 to June 1961. BuMines Rept. of Inv. 6478, 1964, 50 pp.

[37] Elkins, D. A. Estimated Cost of Exploiting Enriched Hard Manganese Ore from the Maggie Canyon Deposit, Artillery Mountains Region, Mohave County, Ariz. BuMines Rept. of Inv. 6438, 1964, 78 pp.

[38] Fuller, H. C., V. E. Edlund, J. W. Sterner, and J. F. McDermaid. Metallurgical Studies of Rhodonite Ores, Silverton District, Colorado (In Three Parts). 3. Melting, Quenching, and Acid Leaching of Concentrates and Electrolytic Recovery of Manganese From Solution. BuMines Rept. of Inv. 6442, 1964, 31 pp.

Ammoniacal-ammonium carbonate leaching of low-grade manganiferous materials from the southern district of Aroostook County, Maine, was studied by the Bureau of Mines on a small laboratory scale. The feed materials, containing from 6 to 16 percent manganese with 2 to 3 times as much iron, were partially reduced with hydrogen or carbon monoxide at 500° to 700° C before leaching. Manganese extractions of 80 to 90 percent were obtained in some instances, but 10 to 34 percent of the iron contained in the samples was extracted as well.[40]

The response to high-temperature sulfatization of different manganese minerals, and of certain gangue materials, was investigated at bench scale by the Bureau at Minneapolis. A low sulfatization of 2 percent was obtained with spessartite garnet (minus 100 mesh) and a high of 98 percent from cryptomelane (minus 100 mesh).[41]

Petrographic study of 96 thin sections of silicate-rich samples from the thin-bedded facies of the main iron-formation of the Cuyuna district of Minnesota showed the following minerals, arranged in decreasing order of abundance: manganese-magnesium-siderite, stilpnomelane, minnesotaite, magnetite, quartz, two unidentified iron silicates, goethite, hematite, pyrite, and, very locally, amphibole and arsenopyrite. Stilpnomelane samples on heating gave a distinct ammoniacal odor and analyzed up to 0.22 percent ammonia.[42]

The rate-of-reaction constants of the MnO–C and Mn_7C_3–3MnO systems at temperatures of 1,100°, 1,150°, and 1,185° C., were reported.[43] The heat of formation of manganous sulfide was determined by hydrochloric acid solution calorimetry.[44]

Deposition of manganese oxide minerals in veins of the southwestern United States was believed to have been the result of the mingling of rising thermal waters, containing manganese in the manganous state, with oxygen-carrying surface waters. As a consequence, exploration of these veins at depths should offer interesting possibilities for finding rhodochrosite and manganese silicates, with barite, fluorite, base-metal sulfides, gold, and silver.[45]

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[39] LeVan, H. P., E. G. Davis, and L. S. Smith. Manganese Extraction Studies Using Ferrous Sulfate and Pickle Liquor. BuMines Rept. of Inv. 6452, 1964, 18 pp.

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The battery-grade manganese oxide ores of Philipsburg, Mont., are of secondary origin, and consist of the following manganese oxide minerals in decreasing order of abundance, as indicated by mineragraphic and X-ray studies: Cryptomelane, Nsuta MnO_2, pyrolusite, todorokite, chalcophanite, manganite, hydrohetaerolite, birnessite, and coronadite. These ores are similar to the battery-grade ores of Nsuta, Ghana.[46]

Water content of various types of battery-grade manganese dioxides were determined, those of higher water content being preferred by the dry-cell manufacturer for certain applications. The types examined were identified as natural ores, electrolytic, chemical, and synthetic hydrous dioxides. Chemical MnO_2 was defined as that obtained by decomposition of manganese carbonate at approximately 250° C in the presence of air and moisture; the resulting manganous oxide is oxidized in an environment of manganese dioxide, and the product is acid leached. The synthetic hydrous MnO_2 was defined as embracing "the so-called hydrates" formed as amorphous byproducts of the oxidation of organic compounds by permanganate. The natural ore samples were found to have the lowest total water content; the synthetic hydrous samples had the highest.[47] Relation of water content to surface area of the four types was established.[48]

Five industry tests used to evaluate the characteristics of manganese dioxide as a battery depolarizer follow: Chemical analyses to determine MnO_2, and hence available oxygen, and to determine harmful impurities; the Kornfeil activity test to obtain an indication of battery activity by measuring the magnitude of available oxygen on a heavy cell discharge; X-ray diffraction analyses to define crystalline structure; differential thermal analysis to indicate the relative quantities of the various crystalline phases; and carbon dioxide evolution, as tested by reducing with oxalic acid with evolution of carbon dioxide, thus giving a measure of the rate and extent to which the manganese dioxide is susceptible to chemical reduction. Characteristic as used here is distinguished from battery activity. The latter can be indicated by certain empirical tests or by the hours of capacity of an actual dry cell subjected to an artificially heavy discharge drain; these conditions are more demanding than the characteristics required of a cell for most of its uses.[49]

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Mercury

By John E. Shelton[1]

◆

MERCURY prices reached an alltime recorded high of $490 to $505 per flask in 1964, domestic production declined to the lowest since 1952, industrial consumption declined from the record high of 1963, and the U.S. Government declared as excess 72,500 flasks of mercury.

World output of mercury was 5 percent higher than in 1963, despite the decrease in U.S. production of almost 5,000 flasks.

Domestic mine production declined 26 percent to 14,142 flasks. Consumption was 12 percent lower than in 1963. The decrease was due primarily to the lower requirements of mercury for installation of new chlorine and caustic soda facilities.

TABLE 1.—Salient mercury statistics

	1955–59 (average)	1960	1961	1962	1963	1964
United States:						
Producing mines	107	75	69	56	[r] 48	72
Production flasks[1]	29,416	33,223	31,662	26,277	[r] 19,117	14,142
Value thousands	$7,234	$7,002	$6,257	$5,024	[r] $3,623	$4,452
Imports:						
For consumption flasks	34,002	19,488	12,326	31,552	42,872	41,153
General do	35,928	19,515	12,527	31,516	43,126	41,107
Exports do	882	357	285	224	187	2,575
Reexports do	1,411	317	180	257	[r] 40	196
Stocks Dec. 31 do	16,516	19,761	17,533	14,924	12,181	16,295
Consumption do	54,346	51,167	55,763	65,301	77,963	82,608
Price: New York, average per flask	$250.76	$210.76	$197.61	$191.21	$189.45	$314.79
World:						
Production flasks	223,000	242,000	240,000	245,000	[r] 239,000	251,000
Price: London, average per flask	$234.97	$197.86	$181.87	$172.79	$171.42	$282.25

[r] Revised.

[1] Flasks as used in this chapter refers to a 76-pound flask.

LEGISLATION AND GOVERNMENT PROGRAMS

The Government offered financial assistance through the Office of Minerals Exploration (OME) to the extent of 50 percent of total allowable costs for exploration of eligible domestic mercury deposits.

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[1] Commodity specialist, Division of Minerals.

Five exploration projects were active in 1964:

Company:	Location	Total cost
T. R. Baugh	Valley County, Idaho	$18, 510
Joseph A. Johnson	San Luis Obispo County, Calif.	21, 160
Pacific Minerals & Chemicals Co., Inc.	Crook County, Oreg	63, 000
J. Selby and Wm. Dawson (assigned to San Simeon Keystone, Inc.).	San Luis Obispo County, Calif.	45, 388
Sonoma International, Inc	Sonoma County, Calif	105, 400

The Atomic Energy Commission (AEC) declared as excess 72,500 flasks of mercury. Of the total, 10,000 flasks was released to the Department of Health, Education, and Welfare for donation to schools and hospitals, and 7,000 flasks was transferred to various Federal agencies. The remaining 55,500 flasks would be made available to the industry through the General Services Administration (GSA). A meeting was held in Washington on November 23 between members of the producing, consuming, and trading industries and representatives of various Federal agencies to discuss selling excess mercury to meet urgent needs of domestic consumers. On December 23, GSA announced a sale by bids to be opened January 15 of 4,000 flasks to help in determining a price for the shelf sale of 10,000 flasks.

DOMESTIC PRODUCTION

Primary output of mercury in the United States declined for the 4th consecutive year. Production was 26 percent less than in 1963; output of 14,142 flasks being the lowest since 1952. All principal mercury-producing States had lower outputs. There were 72 producing mines compared with 48 in 1963. The quantity of ore treated increased 32 percent, but the average grade of ore dropped 5.6 pounds per ton to 7.6 pounds per ton.

California remained the leading mercury-producing State and supplied 73 percent of the domestic total despite a 24 percent decrease in output. The average grade of ore treated decreased from 15.7 pounds per ton in 1963 to 8.0 pounds. The 7 principal producers accounted for 97 percent of the State total.

Nevada remained in second place, supplying 23 percent of the domestic total. Production was 34 percent lower than in 1963. The Cordero mine was the leading producer in the State and ranked second in the United States. Its production was 36 percent lower than in 1963.

The remainder of the 1964 production, 4 percent, was from Alaska, Arizona, Idaho, and Oregon.

Three properties (each producing 1,000 flasks or more) supplied 75 percent of the total domestic output:

State:	County	Mine
California	San Benito	New Idria.
Do	San Luis Obispo	Buena Vista.
Nevada	Humboldt	Cordero.

In addition, these properties produced 100 flasks or more:

State:	*County*	*Mine*
Alaska	Aniak district	Red Devil.
Do	do	White Mountain.
California	Marin	Buena Suerte (Gambonini).
Do	Santa Clara	Guadalupe.
Do	do	New Almaden.
Do	Sonoma	Culver Baer.
Do	do	Mt. Jackson.
Nevada	Nye	Ione Mercury.

These 11 mines produced 95 percent of the domestic output.

TABLE 2.—Mercury produced in the United States, by States

Year and State	Producing mines	Flasks	Value [1] (thousands)	Year and State	Producing mines	Flasks	Value [1] (thousands)
1963:				1964:			
Alaska	2	400	$76	Alaska	3	303	$95
California	31	13,592	2,575	Arizona	4	77	24
Nevada	11	4,944	937	California	39	10,291	3,240
Arizona, Idaho, and Oregon	r 4	r 181	r 35	Idaho	1	83	26
				Nevada	21	3,262	1,027
Total	r 48	r 19,117	r 3,623	Oregon	4	126	40
				Total	72	14,142	4,452

r Revised.
[1] Value calculated at average New York price.

TABLE 3.—Mercury ore treated and mercury produced in the United States[1]

Year	Ore treated (short tons)	Mercury produced		Year	Ore treated (short tons)	Mercury produced	
		Flasks	Pounds per ton of ore			Flasks	Pounds per ton of ore
1955–59 (average)	276,116	29,061	8.0	1962	146,523	26,228	13.6
1960	258,071	33,106	9.7	1963	r 113,539	r 19,101	12.8
1961	262,108	31,633	9.2	1964	149,950	14,115	7.2

r Revised.
[1] Excludes mercury produced from placer operations and from cleanup activity at furnaces and other plants.

Production of mercury from commercial secondary sources was slightly greater than in 1963. Mercury was reclaimed from dental amalgam, oxide and acetate sludges, and battery scrap. Included in the total secondary output was 7,000 flasks transferred to various Government agencies for their own use and 10,000 flasks transferred to the Department of Health, Education, and Welfare for donation to more than 3,000 hospitals and schools.

TABLE 4.—Production of secondary mercury in the United States

Year:	*Flasks*
1960	5,350
1961	8,360
1962	5,800
1963	10,520
1964	23,780

CONSUMPTION AND USES

Industrial consumption of mercury declined 12 percent to 65,608 flasks. In addition, 10,000 flasks of excess AEC mercury was used by schools and hospitals under the donation program of the Department of Health, Education, and Welfare, and 7,000 flasks was used by various Government agencies. The major reason for declining industrial consumption was less mercury used for other uses, including mercury consumed in new and expanded plants producing mercury-cell chlorine and caustic soda. Two such new soda plants were installed at Mobile, Ala., and Geismar, La., compared with three new and two expanded plants in 1963.

Mercury required for replacing losses in manufacturing chlorine and caustic soda rose 20 percent to an alltime high. More mercury was used for amalgamation, 118 percent; agricultural purposes, 24 percent; pharmaceuticals, 24 percent; general industrial laboratories, 22 percent; dental preparations, 11 percent; catalysts, 7 percent; and industrial and control instruments, 1 percent. Usage of mercury declined for manufacturing pulp and paper, 24 percent; antifouling and mildew-proofing paints, 18 percent; and electrical apparatus, 4 percent.

TABLE 5.—Mercury consumed in the United States by uses

(Flasks)

Use	1955–59 (average)	1960	1961	1962	1963	1964
Agriculture (includes fungicides, and bactericides for industrial purposes)	7,500	2,974	2,557	4,266	2,538	3,144
Amalgamation	243	255	278	299	306	667
Catalysts	848	1,018	707	874	612	656
Dental preparations [1]	1,489	1,783	2,154	2,033	2,346	2,612
Electrical apparatus [1]	9,285	9,268	10,255	11,564	11,115	10,690
Electrolytic preparation of chlorine and caustic soda	4,172	6,211	6,056	7,314	7,999	9,572
General laboratory use:						
Commercial	986	1,302	1,484	1,752	[r] 1,241	1,516
Government	---	---	---	---	3,821	17,000
Industrial and control instruments [1]	5,998	6,525	5,627	5,186	4,943	4,972
Paint:						
Antifouling	1,213	1,360	915	124	252	547
Mildew proofing	NA	2,861	5,146	4,554	6,403	4,898
Paper and pulp manufacture	(2)	3,481	3,094	2,600	2,831	2,148
Pharmaceuticals	1,615	1,729	2,515	3,378	4,081	5,047
Redistilled [1]	9,509	9,678	9,013	8,987	9,227	11,405
Other	11,488	2,722	5,962	12,370	[r] 20,248	7,734
Total	54,346	51,167	55,763	65,301	77,963	82,608

[r] Revised. NA Not available.

[1] A breakdown of the "redistilled" classification showed ranges of 45 to 38 percent for instruments, 14 to 8 percent for dental preparations, 44 to 25 percent for electrical apparatus, and 18 to 8 percent for miscellaneous uses in 1955–63, compared with 40 percent for instruments, 21 percent for dental preparations, 24 percent for electrical apparatus, and 15 percent for miscellaneous uses in 1964.

(2) Included with agriculture.

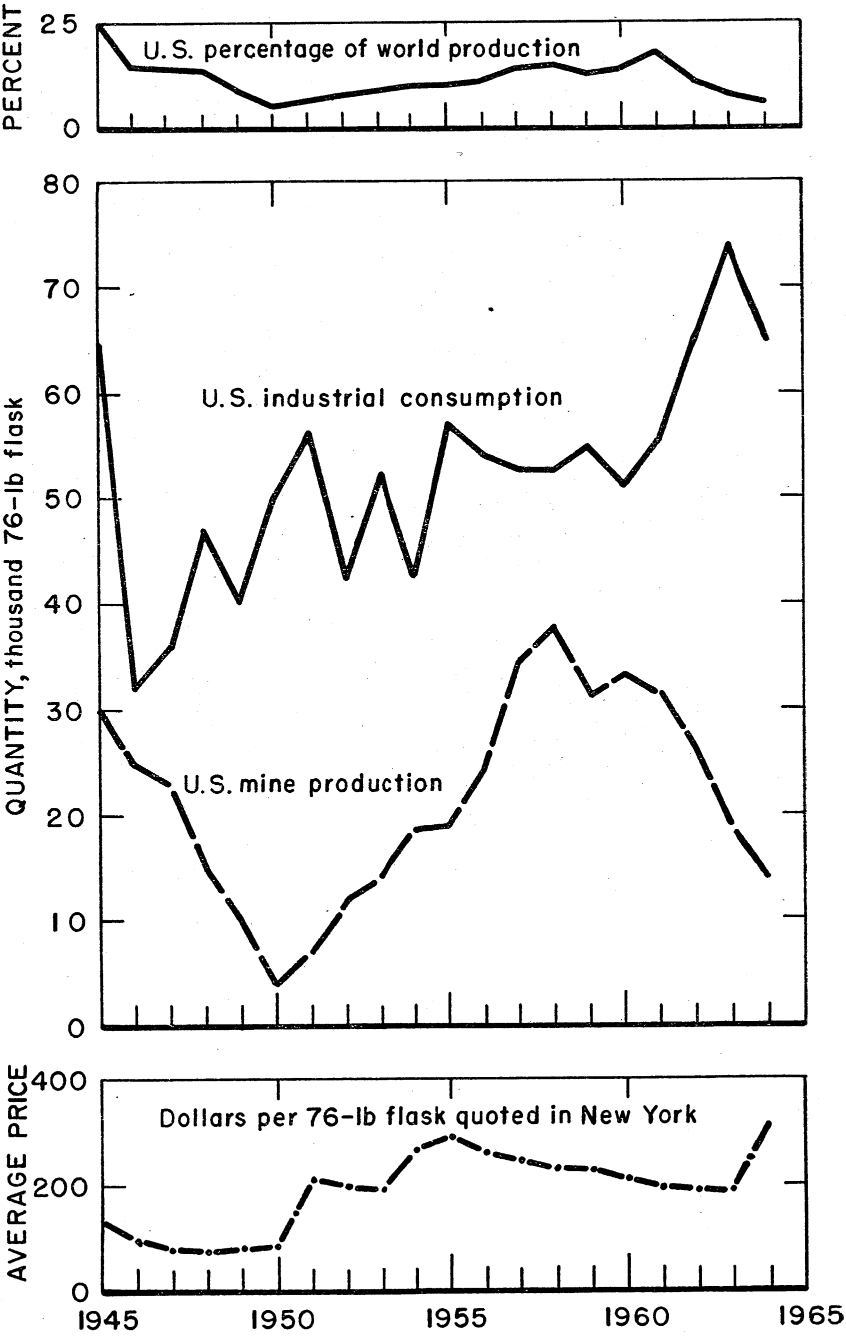

FIGURE 1.—Trends in production, consumption, and price of mercury.

STOCKS

Consumer and dealer stocks were 45 percent more than at the end of 1963. Accumulation of mercury for proposed chlorine and caustic soda plants was mainly responsible for the increase.

Stocks held by producers, usually small in relation to total industry inventories, decreased 43 percent and represented 5 percent of the 1964 total.

On December 31, there was 200,501 flasks in Government stockpiles, of which 16,000 flasks was in the supplemental stockpile. These stocks did not include 72,500 flasks of excess AEC mercury.

TABLE 6.—Stocks of mercury, December 31

(Flasks)

Year	Producer	Consumer and dealer	Total
1955-59 (average)	1,656	14,860	16,516
1960	2,561	17,200	19,761
1961	2,033	15,500	17,533
1962	1,224	13,700	14,924
1963	1,581	10,600	12,181
1964	895	15,400	16,295

PRICES

The average price of mercury for 1964 in the United States was a recorded high of $314.79, up more than $125 per flask over the 1963 average. The price ranged from $228 to $233 per flask at the beginning of 1964 to $490 to $505 per flask at the end of the year.

In London, mercury was quoted at £61 10s ($172.20) per flask at the beginning of the year. The price rose to £140 ($392.00) at the end of the year. The annual average price was £101 1s 9d ($282.25), 65 percent higher than in 1963.

TABLE 7.—Average monthly prices of mercury at New York and London

(Per flask)

Month	1963		1964	
	New York [1]	London [2]	New York [1]	London [2]
January	$186.64	$171.37	$234.36	$219.95
February	187.00	171.01	261.25	243.33
March	187.00	169.44	261.86	243.43
April	184.91	168.04	264.18	243.51
May	183.36	166.86	263.85	246.35
June	182.50	162.41	267.32	244.49
July	182.00	162.45	276.86	259.16
August	182.46	162.38	294.76	278.66
September	187.00	163.67	330.71	285.65
October	192.22	175.14	367.73	337.76
November	200.47	184.65	470.00	382.91
December	217.86	203.45	484.55	390.68
Average	189.45	171.42	314.79	282.25

[1] Engineering and Mining Journal, New York.

[2] Mining Journal (London) prices in terms of pounds sterling were converted to U.S. dollars by using average rates of exchange recorded by Federal Reserve Board.

TABLE 8.—U.S. imports for consumption [1] of mercury, by countries

Country	1955-59 (average)		1960		1961		1962		1963		1964	
	Flasks	Value (thousands)	Flasks	Value (thousands)	Flasks	Value (thousands)	Flasks	Value (thousands)	Flasks	Value (thousands)	Flasks	Value (thousands)
North America:												
Canada	87	$21	20	$5	24	$4	61	$10	150	$27	538	$136
Mexico	7,767	1,668	2,419	382	3,023	445	7,618	1,064	4,292	585	1,230	272
Total	7,854	1,689	2,439	387	3,047	449	7,679	1,074	4,442	612	1,768	408
South America:												
Bolivia	4	1	---	---	---	---	---	---	---	---	106	15
Chile	270	54	139	26	82	15	200	31	740	112	---	---
Colombia	19	3	30	6	25	4	---	---	---	---	---	---
Peru	329	68	49	8	---	---	---	---	3,227	511	3,065	502
Total	622	126	218	40	107	19	200	31	3,967	623	3,171	517
Europe:												
Germany, West	---	---	---	---	---	---	---	---	---	---	(2)	(2)
Italy	6,555	1,492	3,420	627	2,073	365	10,501	1,800	8,474	1,401	5,236	1,262
Netherlands	5	1	---	---	---	---	---	---	---	---	200	49
Spain	16,409	3,555	12,464	2,278	6,544	1,118	9,826	1,638	19,950	3,176	24,344	5,037
Sweden							70	10				
United Kingdom	617	137	---	---	(2)	(2)	(2)	(2)	---	---	75	31
Yugoslavia	1,580	403	900	170	355	62	3,276	537	4,459	696	3,953	939
Total	25,166	5,588	16,784	3,075	8,972	1,545	23,673	3,985	32,883	5,273	33,808	7,318
Asia:												
Israel	---	---	---	---	---	---	---	---	---	---	145	21
Philippines	300	63	---	---	---	---	---	---	1,580	258	1,550	383
Turkey	32	10	---	---	200	35	---	---	---	---	711	128
Total	332	73	---	---	200	35	---	---	1,580	258	2,406	532
Oceania:												
Australia	25	5	---	---	---	---	---	---	---	---	---	---
New Zealand	3	(2)	47	8	---	---	---	---	---	---	---	---
Total	28	5	47	8	---	---	---	---	---	---	---	---
Grand total	34,002	7,481	19,488	3,510	12,326	2,048	31,552	5,090	42,872	6,766	41,153	8,775

[1] Data include mercury imported for immediate consumption plus material withdrawn from bonded warehouses.

[2] Less than ½ unit.

Source: Bureau of the Census.

FOREIGN TRADE

Imports.—Imports of mercury for consumption were 4 percent lower than in 1963. Of the 41,153 flasks received in 1963, Spain supplied 59 percent, Italy 13 percent, Yugoslavia 10 percent, Peru 7 percent; the remaining 11 percent came from Bolivia, Canada, Israel, Mexico, Netherlands, the Philippines, Turkey, the United Kingdom, and West Germany.

Imports of various mercury compounds totaled 8,625 pounds, 42 percent less than in 1963. Of the total, 4,488 pounds came from Spain, and 4,137 pounds came from the United Kingdom.

TABLE 9.—U.S. imports[1] of mercury, by countries

(Flasks)

Country	1955–59 (average)	1960	1961	1962	1963	1964
North America:						
Canada	87	20	24	61	150	538
Mexico	8,157	2,459	3,205	7,560	4,328	1,350
Total	8,244	2,479	3,229	7,621	4,478	1,888
South America:						
Bolivia	4	---	---	---	---	106
Chile	337	139	82	200	740	---
Colombia	25	---	115	---	---	---
Peru	331	49	---	---	3,406	2,657
Total	697	188	197	200	4,146	2,763
Europe:						
Germany, West	---	---	---	---	---	(2)
Italy	6,914	3,447	2,002	10,498	8,474	5,654
Netherlands	4	---	---	---	---	200
Spain	17,155	12,444	6,544	9,826	19,950	24,344
Sweden	---	---	---	70	---	---
United Kingdom	650	---	(2)	(2)	---	75
Yugoslavia	1,904	910	355	3,301	4,498	3,778
Total	26,627	16,801	8,901	23,695	32,922	34,051
Asia:						
Israel	---	---	---	---	---	145
Philippines	300	---	---	---	1,580	1,550
Turkey	32	---	200	---	---	710
Total	332	---	200	---	1,580	2,405
Oceania:						
Australia	25	---	---	---	---	---
New Zealand	3	47	---	---	---	---
Total	28	47	---	---	---	---
Grand total	35,928	19,515	12,527	31,516	43,126	41,107

[1] Data are "general" imports; that is, they include mercury imported for immediate consumption plus material entering the country under bond.
[2] Less than ½ unit.

Source: Bureau of the Census.

Exports.—Of the total mercury exported, 28 flasks (6 in 1963) went to Japan, 56 (42) to Colombia, 30 (41) to Canada, 13 (9) to Mexico, 12 (0) to Bolivia, and 11 (19) to Venezuela. The remaining 38 flasks went to 14 other countries in lots of 10 flasks or less.

Of 196 flasks reexported in 1964, 150 flasks went to Japan and 46 flasks to South Korea.

TABLE 10.—U.S. exports of mercury

Year	Flasks	Value	Year	Flasks	Value
1955–59 (average)	882	$222,200	1962	224	$64,024
1960	357	82,957	1963	187	46,357
1961	285	70,622	1964 [1]	188	52,107

Source: Bureau of the Census.

TABLE 11.—U.S. reexports of mercury

Year	Flasks	Value	Year	Flasks	Value
1955–59 (average)	1,411	$326,835	1962	257	$42,549
1960	317	62,015	1963	[r] 40	[r] 6,400
1961	180	33,067	1964	196	50,284

[1] Excludes 10,275 pounds of spent catalysts, valued at $12,272 and 171,152 pounds of residues, valued at $17,980.

[r] Revised.

Source: Bureau of the Census.

WORLD REVIEW

World production of mercury was 251,000 flasks, 5 percent higher than in 1963, due largely to increased production in Spain.

Italy.—Output in Italy increased 5 percent from 1963. Exports increased 10 percent to 83,523 flasks.

TABLE 12.—World production of mercury, by countries [1]

(Flasks)

Country	1955-59 (average)	1960	1961	1962	1963	1964
North America:						
Mexico	21,891	20,114	18,101	18,855	16,302	• 12,400
United States	29,416	33,223	31,662	26,277	19,117	14,142
South America:						
Chile	1,426	2,876	1,509	791	613	• 170
Colombia	87	149	191	--------	3	--------
Peru	1,081	3,034	3,001	3,483	3,086	3,275
Europe:						
Austria	6	--------	--------	--------	--------	--------
Czechoslovakia [2]	725	725	725	725	725	• 725
Italy	56,775	55,492	55,434	54,535	54,448	57,001
Rumania	383	413	350	222	194	• 190
Spain	49,262	53,369	51,202	52,798	56,954	74,956
U.S.S.R. •	21,900	25,000	25,000	35,000	35,000	35,000
Yugoslavia	13,152	14,069	15,954	16,273	15,838	17,318
Asia:						
China •	17,100	23,000	26,000	26,000	26,000	26,000
Japan	5,382	5,791	5,437	4,199	4,668	• 4,668
Philippines	2,767	3,041	3,167	2,767	2,651	• 2,500
Turkey	1,149	1,339	1,864	2,687	3,042	• 3,000
Africa: Tunisia	85	166	54	--------	--------	--------
World total •	223,000	242,000	240,000	245,000	239,000	251,000

• Estimate.

[1] This table incorporates some revisions. Data do not add exactly to totals shown because of rounding where estimated figures are included in the detail.

[2] Estimate according to the 51st Annual issue of Metal Statistics (Metallgesellschaft), except Czechoslovakia 1964.

TABLE 13.—Italy: Exports of mercury, by countries

(Flasks)

Destination	1963	1964	Destination	1963	1964
Argentina	------	386	Korea:		
Australia	------	1,305	North	------	1,497
Belgium-Luxembourg	2,741	354	South	508	1,134
Bulgaria	------	377	Netherlands	838	1,004
Canada	1,726	719	Norway	------	313
Czechoslovakia	------	1,346	Poland	780	1,105
Finland	499	------	Rumania	2,666	1,201
France	8,639	4,778	Sweden	1,073	461
Germany:			Switzerland	307	891
East	2,074	1,845	Taiwan	------	395
West	12,204	12,682	Turkey	775	------
Hungary	------	653	United Kingdom	13,068	21,666
India	2,419	795	United States	7,803	4,627
Japan	13,222	19,517	Yugoslavia	1,752	3,002
			Other countries	[r] 2,634	1,470
			Total	75,728	83,523

[r] Revised.

TABLE 14.—Mexico: Exports of mercury, by countries

(Flasks)

Destination	1962	1963	Destination	1962	1963
Argentina	320	59	Korea, South	32	306
Brazil	------	1,547	Taiwan	204	121
Canada	412	21	United Kingdom	1,240	229
Colombia	1,023	5	United States	13,561	14,439
Germany:			Other countries	493	97
East	108	------			
West	------	161	Total	21,734	18,863
Japan	4,341	1,878			

Spain.—Spain was the leading producer with 74,956 flasks. Production was 32 percent higher than the 56,954 flasks in 1963.

TABLE 15.—Spain: Exports of mercury, by countries

(Flasks)

Destination	1962	1963	Destination	1962	1963
Australia	641	480	Pakistan	------	581
Austria	523	------	Poland	335	------
Brazil	195	145	Portugal	306	190
Canada	600	4,694	Sweden	1,171	1,801
Czechoslovakia	610	1,420	Switzerland	217	396
France	4,155	5,479	Tunisia	------	320
Germany:			United Arab Republic		
East	580	581	(Egypt)	232	106
West	9,751	2,002	United Kingdom	6,875	5,564
India	6,798	3,438	United States	11,127	15,508
Japan	679	5,660	Other countries	155	335
Netherlands	506	281			
Norway	435	145	Total	45,891	49,126

United Kingdom.—Foreign trade data for the United Kingdom indicated that consumption of mercury decreased 7 percent. Imports, reexports, and apparent consumption in flasks were as follows:

	1955–59 (average)	1960	1961	1962	1963	1964
Imports	19,100	25,300	27,000	20,700	24,600	30,700
Reexports	6,500	4,300	8,400	5,800	3,800	11,400
Apparent consumption	12,600	21,000	18,600	14,900	20,800	19,300

TABLE 16.—United Kingdom: Imports of mercury, by countries

(Flasks)

Country	1963	1964	Country	1963	1964
Canada	238	----------	Spain	6,520	7,000
China	3,505	1,031	Turkey	1,543	445
Italy	11,510	21,366	Yugoslavia	79	----------
France	750	----------	Other countries	115	823
Mexico	207	----------			
Netherlands	100	----------	Total	24,567	30,665

Yugoslavia.—Output in Yugoslavia was 17,318 flasks, 9 percent higher than in 1963; an alltime recorded high.

TABLE 17.—Yugoslavia: Exports of mercury, by countries

(Flasks)

Destination	1962	1963	Destination	1962	1963
Austria	1,677	355	Sweden	450	60
Canada	----------	100	Switzerland	128	150
Czechoslovakia	300	290	United Kingdom	----------	150
France	400	100	United States	4,000	4,501
Germany, West	353	----------	U.S.S.R	----------	2,612
Israel	700	1,000	Other countries	44	31
Italy	580	348			
Poland	900	870	Total	9,532	10,567

WORLD RESERVES

World reserves of mercury minable at $190 per flask under economic conditions existing in 1962 were estimated by the Federal Geological Survey.[2] Data for Spain and the U.S.S.R. are inadequate and the reserve in each country may be much larger. Based on available information, over 53 percent of the world reserve is in Spain and Italy, the leading producers.

TABLE 18.—World mercury reserves minable under 1962 economic conditions

(Thousand flasks)

Country or area	Estimate, March 1962	Country or area	Estimate, March 1962
United States	75	U.S.S.R	300
Mexico	125	Japan	60
South America	20	China	400
Spain	1,000	Turkey	40
Italy	700	Philippines	35
Yugoslavia	400		
Czechoslovakia	5	Total	3,160

A Bureau of Mines study of more than 1,000 domestic mines, prospects, and occurrences indicated the potential resources of mercury by States at selected price levels.[3] The data indicate a nearly sixfold increase in resources for an increase in price from $200 to $500 per flask, based on a constant dollar of 1957–59=100.

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[2] Bailey, Edgar H., and Roscoe M. Smith. Mercury—Its Occurrence and Economic Trends. Geol. Survey Circ. 496, 1964, 11 pp.

[3] Bureau of Mines Staff. Mercury Potential of the United States. BuMines Inf. Circ. 8252, 1965, 376 pp.

At $200 per flask the resource of 140,000 flasks represents an ore grade of 10 pounds of mercury per ton at most domestic mines and 20 pounds of mercury per ton in Alaska. At a price of $1,000 a flask, the grade of ore that could be extracted is 2 pounds of mercury per ton of ore, increasing resources to 1,287,000 flasks.

TABLE 19.—U.S. mercury resources based on 1961 extraction costs and technologies at selected price levels

(Thousand flasks)

State	Price per flask—1957-59 dollars					
	$100	$200	$300	$500	$1,000	$1,500
Alaska	----------	14.5	33.5	69.5	124.5	142.5
Arizona	----------	----------	2.5	8.0	12.0	13.5
Arkansas	----------	----------	----------	4.5	6.5	7.5
California	39.0	112.5	258.0	566.5	853.0	941.0
Idaho	----------	----------	20.5	37.5	65.0	72.0
Nevada	7.5	13.0	34.5	71.5	115.5	157.5
Oregon	----------	----------	12.5	34.5	55.0	71.0
Texas	----------	----------	17.5	35.0	54.0	59.0
Utah	----------	----------	----------	----------	.5	.5
Washington	----------	----------	----------	.5	1.0	1.0
Total	46.5	140.0	379.0	827.5	1,287.0	1,465.5

TECHNOLOGY

The possible application of mercury as a guide in geochemical prospecting was described.[4] The occurrence of abnormal quantities of mercury in rocks and soils in the vicinity of sulfide and precious metal ores has led to the development of techniques to measure minute quantities of mercury by ultraviolet absorption.

Results of studies by the Bureau of Mines on concentration and hydrometallurgical treatment of mercury ores showed that as much as 95 percent of the mercury could be recovered from some ores by flotation and about 95 percent of the mercury in the concentrate could be recovered by leaching at costs comparable to furnace operations.[5]

The solubility of cinnabar in aqueous sodium sulfide solutions was determined at temperatures ranging from 50° C to 250° C.[6]

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[4] James, C. H. The Potential Role of Mercury in Modern Geochemical Prospecting. Min. Mag. (London), v. 110, No. 7, July 1964, pp. 23–32.

James, C. H., and J. S. Webb. Sensitive Mercury Vapour Meter for use in Geochemical Prospecting. Inst. Min. and Met. Bull. (London), v. 73, No. 691, June 1964, pp. 633–641.

Williston, S. H. The Mercury Halo Method of Exploration. Eng. and Min. J., v. 165, No. 5, May 1964, pp. 98-101.

[5] Town, J. W., and W. A. Stickney. Cost Estimates and Optimum Conditions for Continuous-Circuit Leaching of Mercury. BuMines Rept. of Inv. 6459, 1964, 28 pp.

———. Beneficiation and Hydrometallurgical Treatment of Complex Mercury Sulfide Products. BuMines Rept. of Inv. 6569, 1964, 35 pp.

[6] Dickson, F. W. Solubility of Cinnabar in Na_2S Solutions at 50–250° C and 1–1,800 Bars, With Geologic Applications. Econ. Geol., v. 59, 1964, pp. 625–635.

Mica

By Benjamin Petkof[1]

◆

THE SALE or use of domestically produced sheet mica began an upward trend in 1964 for the first time since 1959. Scrap and flake mica production continued its rise. Consumption of all forms of sheet mica increased. Total imports of mica were down; exports showed a slight rise.

TABLE 1.—Salient mica statistics

	1955-59 (average)	1960	1961	1962	1963	1964
United States:						
Domestic, sold or used by producers:						
Sheet mica....thousand pounds..	718	587	526	363	103	243
Value............thousands..	$2,977	$3,108	$3,386	$1,299	$13	$58
Scrap and flake mica thousand short tons..	94	98	99	108	109	115
Value............thousands..	$2,149	$2,698	$2,417	$2,639	$2,776	$3,353
Ground mica[1] thousand short tons..	100	98	103	114	117	116
Value............thousands..	$6,013	$5,193	$5,468	$6,489	$6,805	$6,902
Consumption, block and film thousand pounds..	3,396	2,776	2,536	2,811	2,293	2,618
Value................thousands..	$4,809	$3,988	$3,630	$3,490	$2,782	$3,002
Consumption, splittings thousand pounds..	7,650	6,227	5,514	6,728	6,687	7,608
Value................thousands..	$3,805	$2,875	$2,266	$2,813	$2,588	$3,149
Imports for consumption thousand short tons..	13	11	7	10	13	8
Exports.......................do....	5	4	4	4	4	5
Consumption, apparent,[2] sheet thousand pounds..	12,689	9,219	8,356	11,582	9,112	9,206
World: Production.................do....	330,000	365,000	365,000	390,000	400,000	410,000

[1] Domestic and some imported scrap.

[2] Sheet mica sold or used, plus imports of unmanufactured and manufactured sheet mica, minus exports of sheet mica.

DOMESTIC PRODUCTION

Sheet Mica.—Sheet mica sold or used by producers ceased its decline, and production more than doubled that of 1963. North Carolina held the distinction of being the only sheet mica-producing State.

Scrap and Flake Mica.—The quantity of scrap and flake mica sold or used increased 5 percent over that of 1963; value increased 21 percent. North Carolina was the largest producer with 56 percent of the total tonnage.

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[1] Commodity specialist, Division of Minerals.

Ground Mica.—Sales of ground mica declined about 1 percent compared with that of 1963. However, value rose about 1 percent. Dry-ground mica accounted for 86 percent of the total output. Production was reported by 25 grinders in 21 dry-grinding plants and 7 wet-grinding plants.

No new mica grinders were reported in 1964. Three companies reported no production during 1964, Jolex Mica Co., Fort Collins, Colo., Los Compadres Mica Co., Ojo Caliente, N. Mex., and Mineral Processing Co., Santa Fe, N. Mex. The Carolina-Southern Mining Co., Inc., closed its plant in July 1964. The plant of the Concord Mica Co., Concord, N.H., burned down in January 1965, and will not be rebuilt.

TABLE 2.—**Mica sold or used by producers in the United States**

Year and State	Sheet mica						Scrap and flake mica [2]	
	Uncut punch and circle mica		Uncut mica larger than punch and circle [1]		Total sheet mica			
	Pounds	Value	Pounds	Value	Pounds	Value	Short tons	Value
1955-59 (average)	432,458	$39,448	285,097	$2,937,330	717,555	$2,976,778	93,813	$2,149,408
1960	330,246	21,628	257,155	3,086,343	587,401	3,107,971	97,912	2,697,510
1961	265,444	21,774	260,563	3,363,986	526,007	3,385,760	99,044	2,416,819
1962	263,123	23,450	99,893	1,275,828	363,016	1,299,278	107,702	2,639,297
1963	97,828	9,206	5,133	3,698	102,961	12,904	109,323	2,776,381
1964:								
New Mexico	--------	--------	--------	--------	--------	--------	6,922	104,872
North Carolina	220,586	37,693	22,076	20,788	242,662	58,481	64,010	2,026,682
South Dakota	--------	--------	--------	--------	--------	--------	996	32,328
Undistributed [3]	--------	--------	--------	--------	--------	--------	42,801	1,188,690
Total	220,586	37,693	22,076	20,788	242,662	58,481	114,729	3,352,572

[1] Includes the full-trimmed mica equivalent of hand-cobbed mica, 1955-62.

[2] Includes finely divided mica recovered from mica and sericite schist, and mica that is a byproduct of feldspar and kaolin beneficiation.

[3] Figures include Alabama, Arizona, California, Connecticut, Georgia, Idaho, Pennsylvania, and South Carolina.

TABLE 3.—**Ground mica sold by producers in the United States, by methods of grinding** [1]

Year	Dry-ground		Wet-ground		Total	
	Short tons	Value (thousands)	Short tons	Value (thousands)	Short tons	Value (thousands)
1955-59 (average)	86,122	$3,988	13,577	$2,025	99,699	$6,013
1960	86,225	3,422	12,121	1,771	98,346	5,193
1961	90,519	3,747	12,176	1,721	102,695	5,468
1962	99,936	4,351	13,851	2,138	113,787	6,489
1963	101,943	4,596	15,308	2,209	117,251	6,805
1964	99,245	4,397	16,725	2,505	115,970	6,902

[1] Partly estimated.

CONSUMPTION AND USES

Sheet Mica.—Domestic consumption of sheet mica (block, film, and splittings) reached 10.2 million pounds, an increase of almost 14 percent over 1963.

The quantity of block and film fabricated domestically increased almost 15 percent to nearly 2.6 million pounds. This quantity consisted of 4 percent Good Stained or better, 32 percent Stained and 64 percent lower than Stained. Electronic applications such as tubes and capacitors consumed 65 percent of all qualities. Production of tubes consumed 86 percent of the Stained or better qualities. Fabrication of muscovite block was reported during the year by 18 companies in 9 States. New Jersey had four operating plants during the year, New York had three plants, and North Carolina had four; these three States together produced 54 percent of the domestically fabricated block and film mica.

Consumption of mica splittings increased 14 percent over the 1963 level. Indian muscovite splittings continued to constitute 95 percent by weight of the consumption; the remainder was principally from the Malagasy Republic. Splittings were fabricated by 11 companies in 12 plants. Operations at four plants—two in New York, one in New Hampshire, and one in Massachusetts—required over 5 million pounds of splittings, or about 71 percent of the total consumed.

TABLE 4.—Fabrication of muscovite ruby and nonruby block and film mica and phlogopite block mica, by qualities and end-product uses in the United States in 1964

(Pounds)

Variety, form, and quality	Electronic uses				Nonelectronic uses			Grand total
	Capacitors	Tubes	Other	Total	Gage glass and diaphragms	Other	Total	
Muscovite:								
Block:								
Good Stained or better	981	34,539	2,012	37,532	5,412	--------	5,412	42,944
Stained	7,245	784,857	13,120	805,222	3,944	25,595	29,539	834,761
Lower than Stained [1]	12,580	528,005	240,043	780,628	14,710	854,414	869,124	1,649,752
Total	20,806	1,347,401	255,175	1,623,382	24,066	880,009	904,075	2,527,457
Film:								
First quality	5,326	--------	--------	5,326	--------	--------	--------	5,326
Second quality	62,765	--------	200	62,965	--------	--------	--------	62,965
Other quality	1,800	--------	--------	1,800	--------	--------	--------	1,800
Total	69,891	--------	200	70,091	--------	--------	--------	70,091
Block and film:								
Good Stained or better [2]	69,072	34,539	2,212	105,823	5,412	--------	5,412	111,235
Stained [3]	9,045	784,857	13,120	807,022	3,944	25,595	29,539	836,561
Lower than Stained	12,580	528,005	240,043	780,628	14,710	854,414	869,124	1,649,752
Total	90,697	1,347,401	255,375	1,693,473	24,066	880,009	904,075	2,597,548
Phlogopite: Block (all qualities)	--------	--------	5,100	5,100	--------	15,424	15,424	20,524

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[1] Includes punch mica.

[2] Includes first- and second-quality film.

[3] Includes other-quality film.

Built-Up Mica.—Produced in various forms by domestic fabricators of splittings, built-up mica was used principally as an electrical insulating material. Tape was the form in greatest demand (29 percent), followed closely by segment and molding plate with 25 percent each. Consumption of built-up mica was 5 percent greater in quantity and 6 percent greater in value than in 1963.

Reconstituted Mica.—General Electric Co. at Schenectady, N.Y., and Samica Corp. (subsidiary of Minnesota Mining & Manufacturing Co. at Rutland, Vt.), continued to fabricate this material from specially delaminated mica scrap by papermaking techniques. This sheet material continued to displace built-up mica in various applications.

Synthetic Mica.—Molecular Dielectrics, Inc., Clifton, N.J., and Synthetic Mica Co., Division of Mycalex Corp. of America, West Caldwell, N.J., continued commercial production of synthetic mica flake for use in glass-bonded mica ceramic materials. Molecular Dielectrics continued recovery of high-quality synthetic mica crystals for splitting and punching.

Other Substitutes for Sheet Mica.—Farnam Manufacturing Co., Inc., continued to make heat-resistant mica electrical insulation from natural mica which had been finely divided and bonded with water-soluble aluminum phosphate. Production was in the form of ridged sheets and various shapes.

TABLE 5.—Fabrication of muscovite ruby and nonruby block and film mica in the United States in 1964 by qualities and grades

(Pounds)

Form, variety, and quality	Grade					
	No. 4 and larger	No. 5	No. 5½	No. 6	Other [1]	Total
Block:						
Ruby:						
Good Stained or better	4,910	2,412	722	16,579	----------	24,623
Stained	22,390	14,034	55,129	638,325	62,199	792,077
Lower than Stained	119,290	158,678	62,790	453,067	516,374	1,310,199
Total	146,590	175,124	118,641	1,107,971	578,573	2,126,899
Nonruby:						
Good Stained or better	2,378	708	780	14,455	----------	18,321
Stained	1,882	3,957	2,861	33,984	----------	42,684
Lower than Stained	58,163	115,837	2,887	1,370	161,296	339,553
Total	62,423	120,502	6,528	49,809	161,296	400,558
Film:						
Ruby:						
First quality	935	731	895	525	----------	3,086
Second quality	18,240	26,748	8,235	2,445	----------	55,668
Other quality	----------	----------	----------	----------	1,800	1,800
Total	19,175	27,479	9,130	2,970	1,800	60,554
Nonruby:						
First quality	----------	----------	1,450	790	----------	2,240
Second quality	35	3,125	3,837	300	----------	7,297
Other quality	----------	----------	----------	----------	----------	----------
Total	35	3,125	5,287	1,090	----------	9,537

[1] Figures for block mica include all smaller than No. 6 grade and "punch" mica.

TABLE 6.—Consumption and stocks of mica splittings in the United States, by sources

(Thousand pounds and thousand dollars)

	Indian		Malagasy		Total	
	Quantity	Value	Quantity	Value	Quantity	Value
Consumption:						
1955–59 (average)	7,088	$3,388	[1] 562	[1] $417	7,650	$3,805
1960	5,915	2,642	312	233	6,227	2,875
1961	5,274	2,077	240	189	5,514	2,266
1962	6,382	2,559	346	254	6,728	2,813
1963	6,406	2,413	281	175	6,687	2,588
1964	7,261	2,949	347	200	7,608	3,149
Stocks Dec. 31:						
1955–59 (average)	4,532	2,444	[2] 352	[2] 275	4,884	2,719
1960	2,839	1,270	316	212	3,155	1,482
1961	2,546	1,212	258	167	2,804	1,379
1962	3,588	NA	143	NA	3,731	NA
1963	2,908	NA	172	NA	3,080	NA
1964	3,523	NA	245	NA	3,768	NA

NA Not available.

[1] Includes Canadian, 1955 and 1957–59.

[2] Includes Canadian, 1955–58.

TABLE 7.—Built-up mica [1] sold or used in the United States, by products

(Thousand pounds and thousand dollars)

Product	1963		1964	
	Quantity	Value	Quantity	Value
Molding plate	1,143	$2,965	1,304	$3,887
Segment plate	1,214	2,917	1,317	3,015
Heater plate	524	(2)	(2)	(2)
Flexible (cold)	602	1,755	566	1,572
Tape	1,441	5,911	1,506	6,048
Other	83	2,065	571	2,107
Total	5,007	15,613	5,264	16,629

[1] Consists of alternate layers of binder and irregularly arranged and partly overlapped splittings.

[2] Included with "Other" to avoid disclosing individual company confidential data.

TABLE 8.—Ground mica sold by producers in the United States, by uses

Use	1963		1964	
	Short tons	Value (thousands)	Short tons	Value (thousands)
Roofing	38,980	$1,370	35,119	$1,100
Wallpaper	1,269	188	1,327	209
Rubber	6,979	728	7,634	865
Paint	23,597	1,890	20,782	1,895
Welding rods	1,169	58	944	34
Joint cement	24,625	1,603	(1)	(1)
Other uses [2]	20,632	968	50,164	2,799
Total	117,251	6,805	115,970	6,902

[1] Included with "Other uses" to avoid disclosing individual company confidential data.

[2] Includes mica used for molded electric insulation, house insulation, Christmas tree snow, annealing, plastics, well drilling, and other purposes.

PRICES

Prices offered by mica fabricators for domestic clear sheet mica (roughly trimmed), as reported in E&MJ Metal and Mineral Markets, remained unchanged from 1963 and ranged from 7 to 12 cents per pound for the smallest size (punch) to $4 to $8 per pound for 6 by 8 inch sheets. Stained or electric mica was quoted 10 to 20 percent lower.

North Carolina scrap mica was quoted throughout the year in the E&MJ Metal and Mineral Markets at $30 to $40 per short ton, depending on quality.

Prices listed for dry- and wet-ground mica have remained unchanged since March 1956.

TABLE 9.—Price of dry- or wet-ground mica in the United States in 1964 [1]

(Per pound)

Mica	Cents
Dry-ground:	
Paint, 100 mesh	4
Plastic, 100 mesh	4
Roofing, 20 to 80 mesh	3
Wet-ground: [2]	
Biotite	6½
Biotite, less than carlots [3]	7¼
Paint or lacquer, 325 mesh	8¼
Paint or lacquer, 325 mesh, less than carlots [3]	9
Wet-ground [2]—Continued	
Rubber	8
Rubber, less than carlots [3]	8¾
Wallpaper	8¾
Wallpaper, less than carlots [3]	9
White, 5 to 10 microns	8¼
White, 5 to 10 microns, less than carlots [3]	9

[1] In bags at works, carlots, unless otherwise noted.

[2] Freight allowed east of the Mississippi River, ½ cent higher west of the Mississippi River, 1 cent higher west of the Rockies.

[3] Ex-warehouse or freight allowed east of the Mississippi River.

Source: Oil, Paint and Drug Reporter.

FOREIGN TRADE

Total imports of all forms of mica was almost 36 percent lower than in 1963, because of a major decline in the quantity of scrap mica imported from India. The higher price of scrap material set by the Indian Government in early 1964 was the probable cause of this situation. Total value of imports declined only 24 percent.

Total exports of mica and mica products increased 13 percent in quantity and 14 percent in value compared with 1963 figures. Ground mica continued to account for the bulk of the exports, and increased about 14 percent in quantity. Unmanufactured mica exports decreased by almost 52,000 pounds. Exports of other manufactured mica increased almost 77,000 pounds.

TABLE 10.—U.S. imports and exports of mica

Year	Imports for consumption						Exports	
	Uncut sheet and punch		Scrap		Manufactured		All classes	
	Pounds	Value (thousands)	Short tons	Value (thousands)	Short tons	Value (thousands)	Short tons	Value (thousands)
1955-59 (average)	2,189,864	$4,567	6,115	$72	5,486	$8,003	4,682	$1,486
1960	1,088,021	2,081	6,240	86	4,266	6,139	4,012	1,311
1961	852,648	1,841	3,024	41	3,763	6,115	3,799	1,227
1962	1,110,739	1,796	4,458	55	5,403	7,922	4,028	1,363
1963	1,133,521	1,615	8,150	132	4,353	5,950	4,021	1,392
1964	2,267,681	2,434	2,733	71	4,433	4,566	4,544	1,586

Source: Bureau of the Census.

TABLE 11.—U.S. imports for consumption of mica, by kinds and countries

Year and country	Unmanufactured									
	Waste and scrap, valued not more than 5 cents per pound				Other					
	Phlogopite		Other		Valued not above 15 cents per pound, n.e.s.		Valued above 15 cents per pound		Block [1]	
	Pounds	Value	Pounds	Value	Pounds	Value	Pounds	Value	Pounds	Value
1955-59 (average)	127,199	$1,174	12,102,283	$71,250	142,463	$10,674	2,047,401	$4,556,846	------	------
1960	------	------	12,480,715	86,272	118,980	8,600	969,041	2,071,509	------	------
1961	96,138	1,212	5,951,448	40,053	68,619	4,085	784,029	1,837,127	------	------
1962	------	------	8,916,421	55,150	55,336	4,841	1,055,403	1,791,215	------	------
1963	224,622	7,360	16,075,434	124,528	181,151	8,929	952,370	1,606,553	419,409	$429,506
1964:										
North America: Canada	203,128	5,927	------	------	------	------	100	300	------	------
South America:										
Argentina	------	------	------	------	259,044	10,557	59,304	20,139	------	------
Brazil	------	------	1,681,550	36,571	28,770	1,290	516,179	850,717	797,349	666,124
Europe:										
Austria	------	------	------	------	------	------	------	------	4,700	5,044
France	------	------	------	------	------	------	34	2,397	------	------
United Kingdom	------	------	------	------	------	------	239	1,126	------	------
Asia: India	206,080	1,147	3,154,860	22,549	(2)	(2)	[2] 53,713	[2] 248,666	518,871	566,016
Africa:										
Malagasy Republic	220,130	4,993	------	------	------	------	16,474	18,494	331	420
Tanzania	------	------	------	------	------	------	8,690	38,465	3,883	4,287
Total	629,338	12,067	4,836,410	59,120	[2] 287,814	[2] 11,847	[2] 654,733	[2] 1,180,304	1,325,134	1,241,891

	Manufactured-films and splittings							
	Not cut or stamped to dimensions				Cut or stamped to dimensions		Total films and splittings	
	Not above 12/10,000 of an inch in thickness		Over 12/10,000 of an inch in thickness					
	Pounds	Value	Pounds	Value	Pounds	Value	Pounds	Value
1955–59 (average)	8,264,343	$3,306,926	2,441,743	$3,164,362	61,542	$997,681	10,767,628	$7,468,969
1960	7,184,944	3,035,162	989,099	1,220,861	82,487	1,122,087	8,256,530	5,378,110
1961	5,800,568	2,572,106	1,469,972	1,812,709	67,116	1,140,572	7,337,656	5,525,387
1962	8,615,571	2,814,751	1,746,221	2,554,567	98,645	1,686,564	10,460,437	7,055,882
1963	6,820,647	2,330,633	1,551,752	1,823,742	70,488	1,174,694	8,442,887	5,329,069
1964:								
North America:								
Jamaica	----------	----------	1,360	1,371	641	1,995	2,001	3,366
Mexico	----------	----------	----------	----------	4,438	119,189	4,438	119,189
South America: Brazil	83,815	37,831	19,028	15,465	2,901	10,609	105,744	63,905
Europe:								
Austria	10,250	4,500	----------	----------	----------	----------	10,250	4,500
France	----------	----------	300	2,310	----------	----------	300	2,310
Germany, West	400	417	----------	----------	4	628	404	1,045
Portugal	3,002	586	----------	----------	----------	----------	3,002	586
United Kingdom	956	4,338	----------	----------	3,645	82,417	4,601	86,755
Asia:								
India	7,991,446	2,634,318	73,014	318,126	28,324	469,144	8,092,784	3,421,588
Japan	10,704	1,186	----------	----------	5,270	160,775	15,974	161,961
Laos	15,500	8,110	200	1,062	----------	----------	15,700	9,172
Africa: Malagasy Republic	389,387	210,669	----------	----------	----------	----------	389,387	210,669
Total	8,505,460	2,901,955	93,902	338,334	45,223	844,757	8,644,585	4,085,046

See footnotes at end of table.

Table 11.—U.S. imports for consumption of mica, by kinds and countries—Continued

Year and Country	Manufactured-cut or stamped to dimensions, shape or form		Manufactured—other					
			Mica plates and built-up mica		All mica manufactures of which mica is the component material of chief value		Ground or pulverized	
	Pounds	Value	Pounds	Value	Pounds	Value	Pounds	Value
1955-59 (average)	27,387	$36,748	46,560	$106,475	87,686	$388,182	41,857	$2,546
1960	6,742	8,801	72,384	65,451	152,867	683,793	46,000	2,760
1961	793	1,617	57,609	49,966	105,777	537,270	23,000	1,380
1962	1,537	7,582	141,739	104,872	132,920	748,502	69,000	3,935
1963	1,660	11,626	127,425	99,681	102,198	507,985	31,488	1,636
1964:								
North America:								
Canada	183	2,310	--	--	9,082	28,581	23,000	1,171
Jamaica	--	--	--	--	148	369	--	--
Mexico	--	--	--	--	6,133	32,113	--	--
South America: Brazil	--	--	--	--	18,144	79,285	--	--
Europe:								
Belgium-Luxembourg	--	--	114,674	84,372	19,866	44,772	--	--
France	--	--	--	--	1,931	61,429	--	--
Germany, West	--	--	--	--	166	2,620	--	--
Netherlands	--	--	--	--	155	6,308	--	--
Switzerland	--	--	12	198	--	--	--	--
United Kingdom	--	--	1,100	734	8,979	79,129	--	--
Asia:								
India	1,910	12,549	--	--	15,828	38,239	--	--
Japan	--	--	--	--	961	6,763	--	--
Total	2,093	14,859	115,786	85,304	81,393	379,608	23,000	1,171

[1] Not separately classified prior to Sept. 1, 1963.

[2] Adjusted by the Bureau of Mines to include 2,110 pounds ($12,894) from India. reported by the Bureau of the Census under 15 cents per pound.

Source: Bureau of the Census.

TABLE 12.—U.S. exports of mica and manufactures of mica, by countries

Year and destination	Unmanufactured		Manufactured			
			Ground or pulverized		Other	
	Pounds	Value	Pounds	Value	Pounds	Value
1955–59 (average)	801,721	$78,136	8,215,898	$445,795	345,475	$962,178
1960	701,926	113,101	7,077,245	370,217	243,354	828,461
1961	334,211	141,730	7,074,850	395,563	190,320	689,238
1962	430,856	166,268	7,427,420	432,013	197,441	765,005
1963	594,427	147,573	7,244,428	413,309	204,246	830,783
1964:						
North America:						
Bahamas					1,294	1,891
Canada	268,442	83,850	2,348,954	131,925	139,724	462,206
Canal Zone					3,899	5,045
Costa Rica			4,400	428		
Dominican Republic					930	950
El Salvador			16,000	648	215	1,183
Guatemala			92,410	3,995	52	236
Honduras					232	358
Jamaica			40,000	1,100		
Leeward and Windward Islands	959	1,960				
Mexico	12,380	2,598	181,956	10,805	16,309	61,268
Trinidad and Tobago			30,000	2,964	676	2,460
South America:						
Argentina	342	596	15,500	1,452	8,924	22,246
Bolivia					200	324
Brazil					5,000	12,033
British Guiana					52	208
Chile	190	290			2,186	17,677
Colombia	19,200	760	178,904	10,302	4,485	12,754
Ecuador			49,400	3,700	388	548
Peru			182,076	10,499	7,181	12,040
Surinam			40,000	4,108		
Venezuela	12,740	1,784	719,040	44,434	1,402	6,310
Europe:						
Austria	502	246			70	246
Belgium-Luxembourg			382,750	27,358	521	1,620
Denmark					380	1,353
Finland			3,826	226		
France			777,182	59,647	1,553	3.988
Germany, West	9,773	26,110	1,139,511	54,255	36,594	74,732
Greece	4,400	418	4,480	466	250	320
Iceland			18,800	1,456		
Italy	91,500	11,589	372,950	16.347	798	9,549
Netherlands	10,000	600	310,318	15,772	258	4,350
Norway					108	977
Portugal					483	745
Spain			102,400	5,960	17,282	116,968
Sweden			18,344	1,604	2,358	9,672
Switzerland			13,200	1,154	4,342	7,162
United Kingdom	21,841	10,290	66,000	5,280	1,598	6,740
Asia:						
Bahrein			40,000	3,000		
Hong Kong					84	302
India					615	1,683
Indonesia					80	326
Iran					290	925
Israel	11,418	5,467	10,000	800	90	380
Japan	48,829	12,210	100,000	4,760	650	4,240
Kuwait			195,200	14,640		
Lebanon			9,406	546		
Pakistan			4,000	320	172	356
Philippines	30,000	2,700	54,686	4,379	597	3,069
Taiwan			14,515	958	496	1,241
Thailand			8,000	532	360	384
Turkey			25,300	2,024	1,390	5,947
Africa:						
Congo (Léopoldville)					394	2,509
Liberia					85	176
Libya			232,000	12,900		
Morocco			6,600	554		
Nigeria			232,414	4,636		
Somali Republic			30,000	2,250		
South Africa, Republic of			112,698	4,902	7,773	30,859
Oceania:						
Australia			62,327	3,712	8,311	35,797
New Zealand			17,950	1,436		
Total	542,516	161,468	8,263,497	478,234	281,131	946,353

Source: Bureau of the Census.

WORLD REVIEW

Angola.—The Companhia Mineira do Lobito has filed a claim for a recently discovered mica deposit at Messele, Andulo, in the district of Bie.

Canada.—Phlogopite mica was produced in southwestern Quebec and southeastern Ontario on an intermittent basis during 1963. Scrap phlogopite was dry ground in a plant near Cantley, Quebec, by Blackburn Brothers, Ltd. Production in 1963 was slightly in excess of 1 million pounds. Canada continued to depend on imports for its muscovite mica requirements.[2]

India.—On January 30, 1964, the Indian Government's Ministry of International Trade forbade the export of any unmanufactured mica on a consignment basis effective February 1, 1964. Shipments of mica were permitted if an irrevocable letter of credit equivalent to 90 percent or more of the invoice was submitted. Minimum f.o.b. prices were set on exports of some classes of mica.[3] On July 1, 1964, the Indian Government placed unmanufactured mica under compulsory preshipment inspection. The Mica Export Promotion Council in Calcutta was made responsible for preshipment inspection and the issuance of quality certificates.[4]

The Indian mica industry depression was increased by the Government ban of exports on a consignment basis. About 10 percent of the producers in Bihar State failed to renew their licenses during 1964. In addition, some 85 firms dealing in mica, about 7 percent of Bihar's dealers, have surrendered their licenses and closed their establishments. During 1963, 1,196 dealers' and 171 miners' licenses were issued. In 1964, 1,111 dealers' and 152 miners' licenses were renewed. The closing of trading and mining firms has caused widespread unemployment in the largest producing State.

Exports of all varieties of mica reached almost 33,000 short tons valued at about $20.6 million. This was a decrease of almost 4,600 tons in quantity, but value increased $2 million. About 36 percent of this material consisted of block, film, and splittings.

Malagasy Republic.—Malagasy maintained its status as the world's largest producer of phlogopite mica, exporting over 2 million pounds of block splittings and scrap valued at almost $1 million.

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[2] Reeves, J. E. Mica. Canada Dept. of Mines Tech. Survey, Mineral Processing Div., Mines Branch, Ottawa, Canada, 1963, 6 pp.

[3] Bureau of Mines. Mineral Trade Notes. V. 58, No. 5, May 1964, pp. 36–39.

[4] Bureau of Mines. Mineral Trade Notes. V. 59, No. 2, August 1964, p. 39.

TABLE 13.—World production of mica by countries [1] [2]

(Thousand pounds)

Country [1]	1955–59 (average)	1960	1961	1962	1963	1964 [p]
North America:						
Canada (shipments):						
Block	77	175	155	1,204	1,183	1,203
Splittings	4	---------	22			
Ground	1,063	792	1,434			
Scrap	271	735	205			
United States (sold or used by producers):						
Sheet	718	587	526	363	103	243
Scrap	187,627	195,824	198,088	215,404	218,646	229,458
South America:						
Argentina:						
Sheet	223	190	119	273	75	141
Scrap	2	---------	---------	---------	---------	22
Brazil	2,926	4,440	9,101	3,885	3,289	[3] 3,289
Europe:						
Austria [4]	408	317	194	33	---------	---------
France	71	686	304	190	381	[3] 381
Germany, West	[5] 31	22	18	20	[e] 20	[e] 20
Norway, including scrap	5,600	6,400	7,700	2,200	---------	8,800
Spain	20	(6)	---------	---------	---------	---------
Sweden (ground)	397	348	110	126	---------	---------
Yugoslavia	[7] 15	4	4	4	77	77
Asia:						
India (exports):						
Block	6,638	5,216	4,592	4,396	3,979	4,264
Splittings	15,657	17,469	18,208	18,838	15,595	19,378
Scrap	27,123	42,829	35,355	[8] 45,523	[8] 55,547	[8] 42,256
Pakistan, West	---------	---------	---------	---------	2	9
Taiwan, including scrap	9	---------	---------	---------	---------	---------
Africa:						
Angola:						
Sheet	40	26	4	---------	---------	---------
Scrap and splittings	686	721	51	108	---------	---------
Kenya	9	2	(6)	2	2	(6)
Malagasy Republic (phlogopite):						
Block	157	256	223	181	214	205
Splittings	1,541	1,973	2,002	2,780	1,914	1,299
Mozambique, including scrap	29	2	4	2	---------	---------
Southern Rhodesia:						
Block	110	90	64	33	60	75
Crude and scrap	---------	754	101	172	225	157
South Africa, Republic of:						
Sheet	4	2	2	2	39	36
Scrap	5,020	6,710	5,440	4,900	4,680	6,764
South-West Africa	46	---------	---------	150	1,197	831
Sudan:						
Block	[9] 425	---------	---------	---------	---------	---------
Scrap						
Tanzania (exports):						
Sheet	130	179	196	218	236	207
Scrap	220	---------	---------	---------	---------	320
Zambia, sheet	2	1	---------	---------	---------	4
Oceania: Australia:						
Block	37	9	---------	---------	---------	---------
Scrap	66	648	185	---------	---------	---------
Damourite	1,133	1,252	1,138	1,087	1,100	[3] 1,100
World total (estimate) [1] [2]	330,000	365,000	365,000	390,000	400,000	410,000

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[e] Estimate. [p] Preliminary.

[1] Mica is also produced in China, Rumania, and U.S.S.R., but data on production are not available; estimates are included in the total for China and U.S.S.R.

[2] This table incorporates some revisions. Data do not add exactly to totals shown because of rounding where estimated figures are included in the detail.

[3] 1963 data.

[4] Including reclaimed from dumps; in 1961 and 1962 from dumps only.

[5] Average annual production 1958–59.

[6] Less than ½ unit.

[7] Average annual production 1956–59.

[8] Includes consenser film as follows: 1962, 412 thousand pounds; 1963, 234 thousand pounds; 1964, 198 thousand pounds.

[9] Average annual production 1957–59.

TECHNOLOGY

The heat of formation of muscovite by hydrofluoric acid solution calorimetry was determined. The results were expressed both in terms of the constituent oxides and in terms of the constituent elements.[5]

Heat content measurements and entropy values were conducted for muscovite and dehydrated muscovite. The apparent heat content of the water in muscovite was compared with previous similar information regarding water in hydrated minerals.[6]

Observations were made on the surface structures of natural basal planes of phlogopite crystals from several localities in Japan. The crystals collected from Matsurezima, Shimonoseki-shi, Mutsumimura, Yamaguchi Pref., and Nokono-shima, Fukuoka Pref., occurred in druses of trachybasalt lavas of Pleiocene age.[7]

The apparatus and techniques used to determine crystalline solubility in micas were described. The influence of the solubility on various properties was studied. Three main properties were Powder X-ray spacings, thermal breakdown which affects the petrologic interpretations, and influence on the polytypism in the micas.[8]

The infrared absorption and reflection spectra of samples of natural muscovites and phlogopites were obtained as a function of the orientation of the sample and as a function of temperature. Frequencies of the most intense bands of the mica spectrum were correlated with vibrational modes of the Si-O layer lattice, using a valence force field with three force constants and the actual masses of oxygen and silicon.[9]

X-ray spectographic analysis of unfused pelletized rock powders with glass-like surfaces gave high precision and sensitivity enabling quantitative demonstration of the mineralogical effect of biotite mica on the relative intensities of Si, Al, Ti, Fe, Mn, Mg, Ca, K, and Na. The abnormal increase and decrease in intensity with decreasing grain size was explained by the relative increase of the biotite surface and by assuming known differences in the composition of biotite and granite.[10]

It was reported that mica-bonded mica, a new high temperature insulation material, has a low expansion rate and is resistant to many chemicals.[11]

Selected samples of micas and chlorites compiled from post-1900 literature were used in a study of the (OH,F)/O relation in Al–K dioctahedral micas, Li muscovites and trioctahedral micas, and of the OH/O relation in chlorides.[12]

An insulation system for a.c. and d.c. class B and F motors and generators was reportedly developed from mica paper coated with glass-dacron binder and permeated with epoxy. The tape is wrapped around the coil to be insulated, then cured. Excess resin fills all voids and seals the coil without application of vacuum or pressure.[13]

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[5] Barany, R. Heat and Free Energy of Formation of Muscovite. BuMines Rept. of Inv. 6356, 1964 6 pp.

[6] Pankratz, L. B. High-Temperature Heat Contents and Entropies of Muscovite and Dehydrated Muscovite. BuMines Rept. of Inv. 6371, 1964, 6 pp.

[7] Sunagawa, Ichiro. Growth Spirals on Phlogopite Crystals. Am. Mineral., v. 49, No. 9–10, September–October 1964, pp. 1427–1434.

[8] Crowley, M. S., and R. Roy. Crystalline Solubility in the Muscovite and Phlogopite Groups. Am. Mineral., v. 49, No. 3–4, March–April 1964, pp. 348–362.

[9] Vedder, W. Correlations Between Infrared Spectrum and Chemical Composition of Mica. Am. Mineral., v. 49, No. 5–6, May–June 1964, pp. 736–768.

[10] Volborth, A. Biotite Mica Effect in X-ray Spectrographic Analysis of Pressed Rock Powders. Am. Mineral., v. 49, No. 5–6, May–June 1964, pp. 634–643.

[11] Materials in Design Engineering. Mica-Bonded Mica. V. 59, No. 5, May 1964, pp. 156–158.

[12] Foster, Margaret D. Water Content of Micas and Chlorides. U.S. Geol. Surv. Prof. Paper 474F, 1964, 15 pp.

The use of mica along with glass flakes and glass fiber as a reinforcement in synthetic resin molding compositions was patented.[14]

A method and apparatus was patented for producing synthetic mica.[15]

A new mica mat electrical insulation bonded with a proprietary inorganic binder that can withstand continuous exposure to 1200° F and intermittant exposure to 1400° F was announced. The new insulation offers the lightweight of organic insulations, and approaches the high temperature resistance of ceramics. The mechanical and electrical properties of the mica mat are described.[16]

The mechanism of recrystallization of a synthetic mica glass was studied on the basis of microstructures and reaction kinetics. The glass was first transformed to an intermediate pseudocrystalline phase from which mica crystals subsequently were formed. The kinetics of the reaction leading to the intermediate pseudocrystalline phase were examined by microscopic methods.[17]

A patent was granted for the manufacture of synthetic mica of the fluorophlogopite variety.[18]

A patent was issued for an apparatus for making paper from synthetic mica particles.[19]

A British patent was issued for the manufacture of an insulating material consisting of a mixture of phlogopite or muscovite mica, powdered white glass frit and slate or other mixture of quartz and sericite, and fired to 500° C.[20]

A fire resistant sheet material composed of 15–30 percent micronized mica with polyvinyl chloride and cresyl diphenyl phosphate was patented.[21]

A method was patented for the use of micronized mica in a colloidal silica red lead composition for coating ferrous metal surfaces.[22]

A method was patented for the production of integrated sheet materials from mica flakes and glass fiber.[23]

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[13] Materials in Design Engineering. Coated Mica Repairs Motors. V. 58, No. 7, Dec. 1963, pp. 153, 155.

[14] Brown, A. W. (assigned to Owens-Corning Fiberglass Corp.) Siliceous Reinforced Resins. U.S. Pat. 3,158,528, Nov. 24, 1964.

[15] Shell, H. R., and N. A. Pace (assigned to U.S. Department of the Interior). Progressive Melting and Recrystallization of Synthetic Mica. U.S. Pat. 3,154,381, Oct. 27, 1964.

[16] Materials in Design Engineering. Inorganic Mica Mat Insulation Takes 1400° F. V. 59, No. 1, Jan. 1964, p. 115.

[17] Chen, F. P. H. Kinetic Studies of Crystallization of Synthetic Mica Glass. J. Am. Ceram. Soc., v. 46, No. 10, Oct. 1963, pp. 476–484.

[18] Eppler, R. A., J. F. MacDowell, and J. D. Stether (assigned to Corning Glass Works). Method of Making Crystalline Mica Bodies and Products. U.S. Pat. 3,149,947, Sept. 22, 1964.

[19] Haller, W. K. (assigned to Mycalex Corporation of America). Apparatus for Making Reconstituted Mica Sheet. U.S. Pat. 3,117,907, Jan. 14, 1964.

[20] Wedlock, A. W. H. (assigned to Mycalex Corporation of America and T.I.M. Ltd.) British Pat. 949,401, Feb. 12, 1964.

[21] Fasold, G. A., and J. G. Blough (assigned to the Philip Carey Manufacturing Co.) Fire Resistant Vapor Barrier for Roof Decks and the Like. U.S. Pat. 3,141,858, Aug. 21, 1964.

[22] McMahon, W. W., and C. G. Abba. Inorganic Coating Composition. U.S. Pat. 3,142,583, Aug. 28, 1964.

[23] Hayman, M. D. (assigned to Acim Paper Corp.). Glass Included Integrated Mica Sheet and Method of Production. U.S. Pat. 3,131,114, Apr. 28, 1964.

Molybdenum

By R. W. Holliday[1]

⁂

THE YEAR was one of unprecedented growth in terms of world demand and mine development. As most of the new mining and concentrating facilities were still in a developmental stage at yearend, the growth was not fully reflected in production and consumption data. World production did reach a new high, and the supply to consumers in the United States was augmented by a release of 8 million pounds of molybdenum from the Government stockpile but shortages persisted. Domestic steel producers engaged in record-breaking productivity, and foreign consumers were restricted in their use of molybdenum.

TABLE 1.—Salient molybdenum statistics

(Thousand pounds of contained molybdenum and thousand dollars)

	1955-59 (average)	1960	1961	1962	1963	1964
United States:						
Concentrate:						
Production	54,404	68,237	66,563	51,244	65,011	65,605
Shipments	54,582	69,941	66,753	50,506	65,839	65,097
Value [1]	$62,690	$87,406	$87,925	$69,333	$91,096	$97,121
Consumption	37,830	44,784	42,261	40,990	49,241	56,409
Imports for consumption	32	----------	----------	----------	----------	----------
Stocks, Dec. 31: Mine and plant	4,492	3,481	2,815	3,490	2,436	4,303
Primary products:						
Production	36,778	43,427	41,050	40,074	48,756	55,946
Shipments	38,262	45,777	47,106	46,673	49,599	60,403
Consumption	[2] 24,019	31,837	32,621	35,674	37,478	43,119
Stocks, Dec. 31: Producer	5,159	8,157	5,074	3,068	4,504	4,398
World: Production	71,000	89,100	89,200	75,100	90,900	94,400

[1] Largely estimated by Bureau of Mines.

[2] 1956-59 only.

LEGISLATION AND GOVERNMENT PROGRAMS

In February the Office of Emergency Planning established a new national stockpile objective of 68 million pounds for molybdenum in concentrates, superseding the objective set in February 1960 of 59 million pounds. In April 1964, subobjectives of 19.5 million pounds molybdic oxide and 7.5 million pounds of ferromolybdenum were announced.

Under the new objective an excess of about 11 million pounds remained in the stockpile. Congress authorized release of this excess material on July 14, 1964 (Public Law 88–377), without regard to the normal 6-month waiting period. Sales of 5 million pounds were made in August and of 3 million pounds in October, through General Services Administration.

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[1] Commodity specialist, Division of Minerals.

At yearend the stockpile had an overall excess of 4 million pounds, but the subobjective for molybdenum in ferromolybdenum was only 53 percent filled. Invitations were issued for contracts to upgrade molybdenite in the stockpile to ferromolybdenum in order to meet the subobjective.

DOMESTIC PRODUCTION

Molybdenum production increased slightly, compared with that of 1963, despite work stoppages affecting the two largest producers. Work at the Climax molybdenum mine in Colorado was interrupted for about 6 days because of an explosion and fire in a ventilation raise. A strike idled Kennecott Copper Corp. facilities in Utah, Nevada, Arizona, and New Mexico from July 1 until mid-September.

Initial production came, in the last quarter, from the Mineral Park (Ithaca Peak) mine of Duval Corp. in Mohave County, Ariz., and from the Mission copper mine of American Smelting & Refining Co.

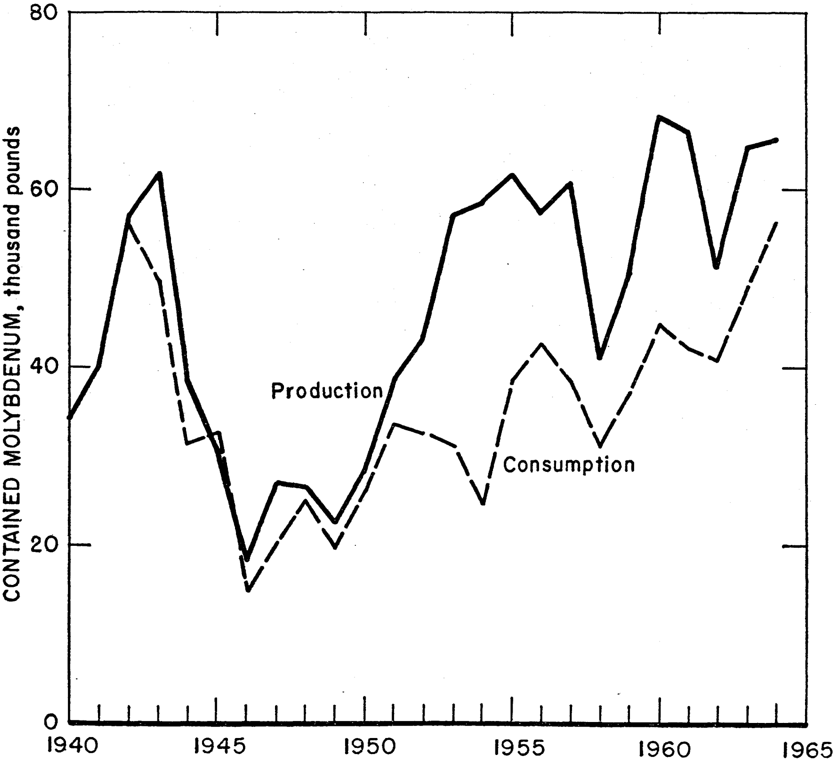

FIGURE 1.—Domestic molybdenum concentrate production and consumption.

(A S & R), in Pima County, Ariz. The Duval production was from a newly developed, open pit, copper operation designed to mine and treat 12,000 tons of ore per day. The molybdenum content of the copper ore reportedly ranged from 0.08 to 0.12 percent.

Production at the Mission mine was expanded to 20,000 tons per day, and a molybdenite recovery unit was installed in the circuit to account for the new A S & R production.

Molybdenite recovered as a byproduct from copper mines in Arizona, Nevada, New Mexico, and Utah and from a tungsten mine in California accounted for 28 percent of the total domestic output.

The Climax Molybdenum Co. mine, in Lake County, Colo., continued as the major world source of molybdenum, accounting for 50 percent of the estimated world production and 72 percent of the domestic output. According to the firm's annual report to its stockholders, a record 13.7 million tons of ore was mined from which 47 million pounds of molybdenum, contained in concentrate, was extracted. Production was started from the Ceresco Ridge deposit, contiguous to the Climax ore body, during the last quarter of 1964. The proven ore reserve at the Climax mine was reported at 430 million tons, enough to support the current rate of mining through the remainder of this century.

Mine development and construction of milling facilities continued at the firm's Urad mine near Empire, Colo. This operation, expected to begin production during 1967, will produce 6 to 7 million pounds per year of molybdenum. Construction of a new plant at the Climax mine site to recover 3 million pounds of molybdenum annually from oxidized ores was started, and initial operation was scheduled for 1966.

The Climax plant at Langeloth, Pa., for producing purified molybdic oxide, was being expanded to double its current capacity. This high-purity oxide is used in the production of metallic molybdenum, molybdenum base alloys, catalysts, and superalloys.

After several years of drilling, testing, and developing, the Questa, N. Mex., molybdenite deposit of the Molybdenum Corp. of America, neared the operating stage. Production was expected to begin in September 1965, reaching capacity in January 1966. This major new molybdenite development, costing $27.5 million, will include the open pit mine, milling facilities to produce 8 to 10 million pounds of molybdenum in concentrate per year, and a townsite.

CONSUMPTION AND USES

Domestic consumption of molybdenum concentrate exceeded the previous record, extablished in 1963, by 15 percent. This was possible because the supply from current domestic mine production was augmented by release of 8 million pounds from Government stockpiles. Small quantities were used in producing purified molybdenum disulfide for lubricants or for direct additions to steel but most concentrate was converted to molybdic oxide for use as such or for conversion to other primary molybdenum products.

Molybdic oxide (MoO_3), produced by roasting of concentrate

TABLE 2.—Production, shipments, and stocks of molybdenum products in the United States

(Thousand pounds of contained molybdenum)

	Product					
	Molybdic oxide [1]		Metal powder		Ammonium molybdate	
	1963	1964	1963	1964	1963	1964
Received from other producers	1,824	3,472	60	368	335	190
Gross production during year	44,951	52,610	1,679	2,253	1,615	1,373
Used to make other products listed here	10,550	12,355	200	761	1,143	1,170
Net production	34,401	40,255	1,479	1,492	472	203
Shipments:						
Domestic consumers	29,490	35,056	1,595	1,854	663	443
Exports	5,937	8,387	----------	173	2	43
Total	35,427	43,443	1,595	2,027	665	486
Producer stocks, Dec. 31	2,492	2,776	419	252	298	205

	Product—Continued				Total	
	Sodium molybdate		Other [2]			
	1963	1964	1963	1964	1963	1964
Received from other producers	32	121	16	200	2,267	4,351
Gross production during year	462	551	11,943	13,463	60,650	70,250
Used to make other products listed here	1	7	----------	11	11,894	14,304
Net production	461	544	11,943	13,452	48,756	55,946
Shipments:						
Domestic consumers	469	687	10,940	12,076	43,157	50,116
Exports	3	11	500	1,673	6,442	10,287
Total	472	698	11,440	13,749	49,599	60,403
Producer stocks, Dec. 31	67	34	1,228	1,131	4,504	4,398

[1] Includes molybdic oxide, briquets, molybdic acid, and molybdenum trioxide.

[2] Includes ferromolybdenum, calcium molybdate, phosphomolybdic acid, molybdenum disulfide, pellets, molybdenum pentachloride, and molybdenum hexacarbonyl.

(MoS$_2$), was used in alloys and compounds; it was converted to other products, or it was exported.

As shown in table 3, 67 percent of the molybdenum consumed in end-use manufacture was in the form of molybdic oxide, and 24 percent was in the form of ferromolybdenum. The iron and steel industries accounted for 85 percent of the molybdenum consumed not including scrap. Although data are not available, it is known that substantial quantities of molybdenum-bearing scrap were remelted.

Ferromolybdenum, metal powder, and the chemicals shown in table 3 were produced from molybdic oxide. Although most ferromolybdenum was used in alloy manufacture, a considerable quantity was used as a coating for welding rods. Molybdenum metal powder was shaped into usable forms either by powder metallurgy methods or by arc casting. Although quantities used were small compared with quantities used by the iron and steel industries, molybdenum metal and molybdenum-base alloys were virtually indispensable in a wide range of applications. They were used in the electronic and electric industries, in missiles and aircraft, in metalworking, in the

TABLE 3.—Consumption of molybdenum products by end uses, in 1964

(Thousand pounds of contained molybdenum)

End use	Molybdic oxides[1]	Ferro-molybdenum[2]	Molybdenum metal powder	Ammonium molybdate	Sodium molybdate	Other[3]	Total
Steel:							
High speed	1,444	616	1			94	2,155
Hot work tool	247	214				80	541
Other tool	321	233					554
Stainless	4,264	2,533	7			36	6,840
Other alloy[4]	18,185	2,209				255	20,649
Steel mill rolls	1,824	357					2,181
Gray and malleable castings	444	3,068	2			11	3,525
Welding rods		249					249
High-temperature alloys	745	294	9			474	1,522
Molybdenum powder:							
Wire, rod and sheet			1,146				1,146
Other (forging billets, etc.)		11	214				225
Chemicals:							
Inorganic pigments	517			11	12		540
Organic pigments	136			10	178	1	325
Catalysts	722			237	4		963
Miscellaneous[5]	96	730	36	32	21	789	1,704
Total	28,945	10,514	1,415	290	215	1,740	43,119
Stocks at consumer plants, Dec. 31	2,633	1,573	29	141	32	249	4,657

[1] Includes technical and purified oxides.
[2] Includes molybdenum silicide and calcium molybdate.
[3] Includes thermite molybdenum and molybdenum pellets, purified molybdenum disulfide, and molybdenite concentrate added direct to steel.
[4] Includes quantities that were believed used in producing high-speed and stainless steels because some firms failed to specify individual uses.
[5] Includes magnets, other special alloys, friction material, lubricants, pesticides, refractories, packings, etc.

chemical, glass, and metallizing industries, and in nuclear energy applications. A publication[2] issued by the Climax Molybdenum Co. provided a comprehensive review of the developing need for molybdenum in nuclear energy applications.

Molybdic oxide (roasted concentrate) produced for export, shown in table 2, is combined with exported concentrate. Therefore an exact export total is not available. However, reports from industry indicate that about 8.4 million pounds of molybdenum in oxide form was exported compared with about 5.9 million pounds in 1963.

STOCKS

The industrial inventory, reported to the Bureau of Mines, was 13,358,000 pounds, comprised of 4,303,000 pounds in concentrate at mines and plants, 4,398,000 pounds in products at producers plants, and 4,657,000 pounds in products at consumers plants.

The national (strategic) stockpile contained 72,077,936 pounds of molybdenum on December 31, exceeding the objective by 4,077,936 pounds. Of this 72-million-pound inventory, 4,025,185 pounds was contained in ferromolybdenum and 19,554,271 was in molybdic oxide.

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[2] Climax Molybdenum Co. Molybdenum for Nuclear Energy Applications. New York, 1964, 111 pp.

PRICES

American Metal Climax announced price increases, effective April 3, representing the first change since June 1, 1961. The old and new prices are listed below:

	Per pound of contained molybdenum	
	Old	*New*
Molybdenite concentrate, f.o.b. Climax, Colo	$1. 40	$1. 55
Bagged molybdic oxide	1. 59	1. 74
Technical molybdic oxide in cans, f.o.b. Langeloth, Pa	1. 60	1. 75
Molybdic oxide briquets	1. 61	1. 77
Ferromolybdenum	1. 89	2. 04
Technical thermite metallic molybdenum	2. 23	2. 38

Molybdenum powder, carbon reduced, at $3.35, was unchanged. Molybdenum powder, hydrogen reduced, was increased from $3.55 to $3.75 per pound, effective September 14. Because of shortages throughout the year, the above prices were not a true reflection of the supply-demand situation outside of established channels. Sales, especially in foreign markets, were rumored to be at substantially higher prices than those listed above.

The stockpile sales ranged in price from $1.5951 to $2.19 per pound of molybdenum in concentrate.

FOREIGN TRADE

Imports.—Except for 26,750 pounds of crude ore from Canada, presumably for test purposes, there were no imports of molybdenum ore and concentrate into the United States.

Imports of wrought molybdenum totaled 12,287 pounds valued at $150,855; unwrought molybdenum 325 pounds valued at $2,116; waste and scrap 284,924 pounds valued at $156,475. There were no imports of ferromolybdenum.

Exports.—Exports of molybdenum in ore and concentrate (including roasted concentrate) were slightly lower than in 1963, table 6, because supplies were not available to satisfy the high level of foreign demand.

Because of the shortage of concentrate and molybdic oxide, demand for other forms increased markedly as shown in table 5.

TABLE 4.—Molybdenum reported by producers as shipments for export from the United States

(Thousand pounds of contained molybdenum)

Product	1963	1964
Molybdenite concentrate	18, 825	13, 791
Molybdic oxide	5, 937	8, 387
All other primary products	505	1, 900

TABLE 5.—U.S. exports of molybdenum products

(Pounds, gross weight)

Product and country	1963	1964
Ferromolybdenum:[1]		
United Kingdom	1,454	458,324
Canada	125,869	271,605
Japan	44,104	241,534
Germany, West	------------	182,869
India	4,775	113,000
Other countries	62,832	478,279
Total	239,034	1,745,611
Value	$379,173	$3,328,494
Metal and alloys in crude form and scrap:		
Germany, West	10,097	796,163
United Kingdom	------------	232,066
Japan	------------	124,090
Austria	------------	69,984
Canada	107,189	63,977
Other countries	21,916	118,222
Total	139,202	1,404,502
Value	$178,542	$3,629,553
Wire:		
Canada	3,038	13,096
Brazil	4,825	6,292
Netherlands	------------	5,466
Other countries	23,029	6,049
Total	30,892	30,903
Value	$631,397	$499,532
Powder:		
Germany, West	------------	148,295
Venezuela	------------	32,741
Austria	------------	27,000
Belgium-Luxembourg	------------	25,515
Sweden	15,600	24,400
France	------------	22,049
Other countries	1,141	30,957
Total	16,741	310,957
Value	$57,674	$1,177,737
Semifabricated forms, not elsewhere classified:		
Netherlands	116	8,045
Canada	2,488	5,519
Other countries	6,505	21,386
Total	9,109	34,950
Value	$109,990	$289,873

[1] Ferromolybdenum contains about 60 to 65 percent molybdenum.

Source: Bureau of the Census.

TABLE 6.—U.S. exports of molybdenum ore and concentrate (including roasted concentrate), by countries

Destination	1963		1964	
	Molybdenum content (pounds)	Value	Molybdenum content (pounds)	Value
North America:				
Canada	689,561	$915,305	563,697	$871,265
Mexico	3,047	4,550	8,864	13,746
Total	692,608	919,855	572,561	885,011
South America:				
Argentina	766	1,114	2,473	3,358
Brazil	4,663	7,019	1,353	1,575
Chile	9,600	15,456	10,315	16,536
Colombia	522	784	516	860
Peru	---	---	500	800
Venezuela	52,676	77,366	9,831	15,456
Total	68,227	101,739	24,988	38,585
Europe:				
Austria	2,189,892	3,572,473	1,899,531	3,209,906
Belgium-Luxembourg	24,300	38,285	255,731	584,462
Denmark	---	---	44,500	47,558
France	4,717,796	6,809,024	4,068,259	6,118,975
Germany, West	6,210,251	9,186,938	4,701,301	8,130,082
Greece	---	---	144	206
Italy	1,293,833	1,868,202	1,365,701	2,093,923
Netherlands	60,074	88,790	347,591	677,746
Spain	5,415	8,147	4,316	6,025
Sweden	1,354,195	2,050,506	2,002,671	3,076,515
United Kingdom	5,778,771	8,202,668	4,400,901	6,920,870
Total	21,634,527	31,825,033	19,090,646	30,866,268
Asia:				
Hong Kong	2,425	3,752	2,103	3,192
India	590	836	---	---
Japan	4,141,581	6,500,265	5,188,252	9,059,760
Philippines	3,680	6,087	4,500	7,290
Total	4,148,276	6,510,940	5,194,855	9,070,242
Africa: South Africa, Republic of	1,428	2,258	4,027	6,130
Oceania: Australia	---	---	52,703	120,613
Grand total	26,545,066	39,359,825	24,939,780	40,986,849

Source: Bureau of the Census.

TABLE 7.—U.S. import duties

(Per pound)

Item	Articles	Rate of duty[1]
601.33	Molybdenum ore (molybdenum content)	24 cents on molybdenum content.
607.40	Ferromolybdenum (molybdenum content)	20 cents on molybdenum content plus 6 percent ad valorem.
	Molybdenum:	
628.72	Unwrought (molybdenum content)	Do.
628.74	Wrought	25.5 percent ad valorem.
	Chemical elements:	
419.60	Molybdenum compounds (molybdenum content)	20 cents on molybdenum content plus 6 percent ad valorem.
420.22	Potassium molybdate (molybdenum content)	Do.
421.10	Sodium molybdate (molybdenum content)	Do.
473.18	Molybdenum orange	10 percent ad valorem.
417.28	Ammonium molybdate	20 cents on molybdenum content plus 6 percent ad valorem.

Not applicable to Communist countries.

WORLD REVIEW

Large increases in productive capacity, especially in the United States and Canada, and plans for expansion in Chile foreshadowed a substantial increase in world molybdenum output, but shortages in European countries, in Japan, and in the United States were expected to continue at least through the first half of 1965.

The Climax Molybdenum Co., division of American Metal Climax, Inc., announced the start of construction in Rotterdam, Holland, of a $5 million plant for converting molybdenite concentrate to molybdenum products. The plant, designed to process 12 million pounds of concentrate per year, was scheduled for completion in 1966.

Bulgaria.—Opening ceremonies were held on December 29 for the first stage of the new Medet Copper Complex in the Sredna-Gora Mountains designed for annual production of copper concentrate (153,000 tons), molybdenum-calcium concentrate (500 tons), pyrite concentrate (55,000 tons), and feldspar concentrate (50,000 tons). Development of the open pit mine involved removal of 6 million cubic meters of earth and rock and required 3 years.

TABLE 8.—World production of molybdenum in ores and concentrates by countries [1]

(Thousand pounds)

Country	1955-59 (average)	1960	1961	1962	1963	1964 [p]
Canada	820	768	771	818	834	1,278
Chile	3,395	4,083	4,037	5,256	6,400	8,594
China [e]	2,700	3,300	3,300	3,300	3,300	3,300
Japan	619	840	807	825	732	611
Korea, South	44	97	71	163	154	[e] 220
Mexico	44	132	7	128	90	[e] 65
Norway	423	542	531	575	443	[e] 443
Peru	(2)	----------	[3] 937	11	1,175	862
Philippines	[4] 97	62	249	249	236	231
U.S.S.R. [e]	8,400	11,000	11,900	12,500	12,500	13,200
United States	54,404	68,237	66,563	51,244	65,011	65,605
World total (estimate)	71,000	89,100	89,200	75,100	90,900	94,400

[e] Estimate. [p] Preliminary.

[1] Small quantities of molybdenum were also produced in Australia, Austria, Portugal, Republic of South Africa and Yugoslavia during the 1955-59 period; and in Australia in 1961-63.

[2] Less than ½ unit.

[3] Exports.

[4] 1 year only, as 1959 was the first year of commercial production.

Canada.—Productive capacity was expected to grow from the 1 million pounds in 1963 to 15–20 million pounds within the next 5 years. Production continued from the Lacorne, Quebec, mine of the Molybdenite Corp. of Canada, Ltd., which has operated almost continuously since 1942, and from the Gaspe Copper Mines, Ltd., by-product plant from which first shipments were made in 1963.

Initial production, in 1964, came from Bethlehem Copper Corp., Ltd., in British Columbia, from Pax International Mines, Ltd., in Ontario, and Preissac Molybdenite Mines, Ltd., in Quebec.

By far the largest Canadian development, scheduled for production early in 1965, was at the Endako Mines, Ltd. property 4 miles south of Endako in British Columbia. At full production, the mill was designed to treat 10,000 tons of ore daily from the open pit mine. The reserve was estimated to be 67 million tons averaging 0.207 percent MoS_2 and there was reported to be a substantial additional quantity of lower grade material. On this basis, annual output will be on the order of 6 million pounds of molybdenum in concentrate.

Anglo American Molybdenite Mining Corp. in the Cadillac area of Quebec and Noranda Mines, Ltd., at its Boss Mountain property in British Columbia were both building 1,000-ton-per-day mills for production beginning in 1965.

Chile.—Production of molybdenum increased by 34 percent, compared with that of 1963. However, of much greater significance was the announced agreements between the administration of newly elected President Eduardo Frei and the large copper companies. These agreements, still subject at yearend to approval by the Chilean Congress, envisioned a doubling of copper production by 1970. Realization of such copper expansion would increase byproduct molybdenum output by nearly 4 million pounds per year, and some estimates suggest a total output on the order of 12 million pounds by 1970.

China.—Little information about the present molybdenum industry in mainland China was available. However, the past history of production and fragmentary news of sales to free world nations during recent periods of shortage confirmed the view that a potential exists for large scale production.

Japan.—Japanese demand, which far exceeded the nation's mine production, was an important factor in the world market as supply from traditional sources failed to satisfy the increased requirements. Although Climax continued as the major supplier, some 382 short tons of ferromolybdenum was imported from the U.S.S.R. during the January–August period. Belgium (68 tons), the Netherlands (50 tons), and Austria (5 tons) supplied additional quantities. According to one report, 100 tons of concentrate was purchased from mainland China.

A midyear estimate by the Japanese Ministry of International Trade and Industry placed 1964 consumption at 7.4 million pounds, contained molybdenum, compared with 5.5 million pounds in 1963. However, yearend data were not available.

Duval Corp. in Arizona and Endako Mines, Ltd., in British Columbia concluded sales agreements for future shipments to Japan beginning in 1965.

TECHNOLOGY

Improved techniques for extracting molybdenum from molten-salt electrolytes were described.[3] In related research[4] a technique was demonstrated for direct electrolytic production of dimolybdenum carbide (Mo_2C) from molybdenite concentrate (MoS_2); high purity molybdenum metal was then produced by sintering a mixture of the carbide and molybdic oxide.

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[3] Heinen, H. J., and J. B. Zadra. Electrodeposition of Molybdenum Metal From Molten Electrolytes. BuMines Rept. of Inv. 6444, 1964, 17 pp.

[4] Baker, Don H., Jr. Electrowinning Molybdenum and Tungsten. J. Metals, v. 16, No. 11, November 1964, pp. 873–876.

Fundamental research[5] was conducted on the behavior, during rolling, of very large molybdenum single crystals produced by electron beam melting. Single crystal grains with sections of 1 inch and lengths up to 15 inches were used.

The thermodynamic properties of molybdenum compounds were determined.[6]

A method of dry, percussion drilling, using a water-detergent mist, reportedly gave exceptionally accurate results in sampling a molybdenite ore body. According to a brief description,[7] the water-detergent mixture introduced into the air stream causes dust particles to combine into small damp pellets.

Probably the largest nonnuclear mining explosion in U.S. history was set off at the Climax Molybdenum Co. mine in Colorado in May. Nearly 200 tons of ammonium-nitrate-base explosive was detonated in a single blast to loosen a block of ore adjacent to earlier caving operations. Some 1.25 million tons of ore was dropped into position for removal through existing mine workings.

Growing emphasis on extractive metallurgy was highlighted by the announcement that Climax planned construction of a plant for hydrometallurgical extraction of molybdenum from oxidized ores.

In other extractive research, industry metallurgists conducted flotation studies in many domestic and foreign areas, relative to investigations of individual molybdenum deposits. According to a report from the U.S.S.R.,[8] sodium sulfite (Na_2SO_3) is superior to sodium sulfide (Na_2S) for depressing sulfides, other than molybdenite, in an alkaline pulp. Promising results in leaching molybdenite ores with sodium hypochlorite were reported both in the United States and in the U.S.S.R.

Two reports[9] described research on development of continuous process methods for producing metallic molybdenum.

A TZM alloy manufactured by powder metallurgy techniques was announced by Sylvania Electric Products, Inc. Research on hydrostatic extrusion of arc-cast TZM alloy at room temperature was described.[10] Among improvements in physical properties, attributed to the high-pressure extrusion working, were increases of 50 percent in ultimate tensile strength and yield strength.

Molybdenum sheet protected by a modified silicide coating, chromalloy's W-3, reportedly withstood temperatures of 3,000° F without damage during glide reentry tests of the Asset space vehicle conducted by the Air Force. A study of the behavior of molybdenum disilicide under vacuum [11] indicated that loss of silicon above 1,600° C resulted in decomposition of $MoSi_2$. Coatings of molybdenum disilicide on molybdenum metal when exposed at high temperatures to reduced-pressure, oxidizing environments tend to lose silicon by oxidation, volatilization, and inward diffusion, factors partly responsible for accelerated failure observed under these conditions.

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[5] Blickensderfer, R., R. Siemens, G. Asai, and H. Kato. Rolled Molybdenum Single Crystals. BuMine Rept. of Inv. 6539, 1964, 34 pp.

[6] Weller, W. W., and K. K. Kelley. Low-Temperature Heat Capacities and Entropies at 298.15° K of Lead Molybdate and Lead Tungstate. BuMines Rept. of Inv. 6357, 1964, 5 pp.

Mah, Alla D. Heats of Combustion and Formation of Carbides of Tungsten and Molybdenum. BuMines Rept. of Inv. 6337 1964, 9 pp.

[7] Malmgren, Carl. Dry Percussion Drilling With Detergent Mist. Mining Congress J., v. 51, No. 1, January 1965, p. 62.

[8] Laptev, S. F., and K. A. Mamleev. Concentration of Crude Molybdenum Ore Fines. Chem. Abs., v. 61, No. 2, July 20, 1964, col. 1541.

[9] Kay, Herbert, and B. G. Langston. Hydrogen Reduction of Molybdic Oxide, 1. By a Gas Recycle System. J. Metals, v. 16, No. 11, November 1964, pp. 877-881.

Michael, A. B., and J. B. Hanway, Jr. Hydrogen Reduction of Molybdic Oxide, 2. By a Fluidized-Bed Reactor. J. Metals, v. 16, No. 11, November 1964, pp. 881-884.

[10] Air Force Materials Laboratory. Research on Hydrostatic Extrusion of the TZM Alloy at Ambient Temperature. Tech. Documentary Rept. ML-TDR-64-205, June 1964, 92 pp.

Properties and performance of molybdenum disilicide heating elements were reviewed.[12]

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[11] Cherniack, George G., and A. Grant Elliott. High-Temperature Behavior of $MoSi_2$ and Mo_5Si_3. Am. Ceram. Soc., v. 47, No. 3, March 1964, pp. 136-141.

[12] Smoke, Stephan D. How To Use $MoSi_2$ as a Heating Element. Ceram. Ind. Mag., v. 82, No. 4, April 1964, pp. 115-117.

Nickel

By Glen C. Ware[1]

◆

THE NICKEL industry reached new highs in consumption and in producing capacity. The consumption of nickel in the free world increased 20 percent, due largely to the growing use of stainless steels.

In the United States the use of nickel in stainless steels increased 41 percent from 34,100 tons to 48,300 tons. It accounted for about 33 percent of total domestic nickel consumption and 40 percent of free world consumption for stainless steel.

Productive capacity increased in pace with consumption. All of the producing areas of the world reported increased capacity in 1964. Exploration to extend reserves of ore were pressed successfully in the producing areas, and the major producers have directed attention to silicate ores which constitute the largest world reserve of nickel. There looms a wide expansion of the development of these reserves when political and economic conditions become favorable.

Legislation and Government Programs.—In 1964 the General Services Administration (GSA) sold from the Defense Production Act inventory 1,110 tons of electrolytic nickel, 309 tons of nickel oxide powder, and 250 tons of nickel contained in ferronickel. GSA committed 7,654 tons of electrolytic nickel to the Federal Government, 5,000 tons going to the Mint.

Federal Government stockpile inventories on December 31, 1964, given in nickel content, were ferronickel 38,000 tons, nickel metal 150,000 tons, and oxide powder 29,000 tons including the cobalt content, making a total inventory of 217,000 tons of nickel. Of this, 167,000 tons was in the national stockpile and 50,241 tons in the

TABLE 1.—Salient nickel statistics

(Short tons)

	1955-59 (average)	1960	1961	1962	1963	1964
United States:						
Mine production	10,313	14,079	13,133	13,110	13.394	15,420
Plant production:						
Primary	8,789	14,303	11,176	11,217	11,432	12,185
Secondary	11,057	9,431	10,688	11,108	r 18,996	23,114
Imports for consumption	125,400	103,000	127,000	123,000	119,000	129,000
Exports	21,129	54,109	55,493	27,641	60,927	68,502
Consumption	110,364	108,159	118,515	118,677	124,478	146,920
Stocks Dec. 31: Consumer	14,884	11,369	18,298	13,450	17,191	17,076
Price, cents per pound	74	74	74-81¼	81¼-79	79	79
World: Production	286,000	r 353,000	r 398,000	r 394,000	r 395,000	427,000

r Revised.

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[1] Commodity specialist, Division of Minerals.

Defense Production Act stockpile. These two stockpiles contain an excess of 334 percent over the objective of 50,000 tons. There were no stockpile supply contracts in effect.

Bids were received on the first offering in a long-range plan to dispose of about 170,000 tons of nickel over a period of 12 years.

DOMESTIC PRODUCTION

Primary Nickel.—The United States produced ferronickel from domestic ore and nickel salts, chiefly nickel sulfate, as a byproduct of copper refining. The Hanna Mining Co. at Riddle, Oreg., mined 1,070,900 dry tons of ore containing 15,420 tons of nickel. The Hanna Nickel Smelting Co. processed the ore into 23,187 tons of ferronickel containing 11,236 tons of nickel. Copper refiners at Carteret and Barber, N.J., Laurel Hill, N.Y., Baltimore, Md., Tacoma, Wash., and El Paso, Tex., produced nickel salts containing 949 tons of nickel and shipped salts containing 886 tons of nickel.

Chemical companies produced nickel salts containing 2,748 tons of nickel from primary nickel and nickel scrap. They shipped salts containing 2,268 tons of nickel.

Secondary Nickel.—Of the 23,000 tons of secondary nickel recovered, 58 percent was from ferrous and high-temperature alloys, and 15.3 and 8.6 percents were from copper-base and nickel-base alloys, respectively. Stainless-steel scrap was unreported, but large amounts were remelted or exported.

TABLE 2.—Primary nickel produced in the United States

(Short tons, nickel content)

	1955–59 (average)	1960	1961	1962	1963	1964
Byproduct of copper refining	514	623	625	648	707	949
Domestic ore	8,275	[1] 13,680	10,551	10,569	10,725	11,236

[1] Includes 1,773 tons from Cuban concentrate.

TABLE 3.—Nickel recovered from nonferrous scrap processed in the United States, by kind of scrap and form of recovery

(Short tons)

Kind of scrap	r 1963	1964
New scrap:		
Nickel-base	3,616	2,775
Copper-base	2,005	2,448
Aluminum-base	581	476
Total	6,202	5,699
Old scrap:		
Nickel-base	11,879	16,559
Copper-base	537	586
Aluminum-base	378	270
Total	12,794	17,415
Grand total	18,996	23,114

Form of recovery	r 1963	1964
As metal	1,619	1,567
In nickel-base alloys	2,079	1,996
In copper-base alloys	2,679	3,534
In aluminum-base alloys	998	782
In ferrous and high temperature alloys [1]	9,320	13,382
In chemical compounds	2,301	1,853
Total	18,996	23,114

r Revised.

[1] Includes only nonferrous nickel scrap added to ferrous and high-temperature alloys.

TABLE 4.—Stocks and consumption of new and old nickel scrap in the United States in 1964

(Gross weight, short tons)

Class of consumer and type of scrap	Stocks beginning of year	Receipts	Consumption			Stocks, end of year
			New	Old	Total	
Smelters and refiners:						
Unalloyed nickel	191	1,040	728	319	1,047	184
Monel metal	381	1,679	479	1,177	1,656	404
Nickel silver [1]	725	4,189	367	3,709	4,076	838
Miscellaneous nickel alloys	14	4,300	4	4,303	4,307	7
Nickel residues	87	29		36	36	80
Total	673	7,048	1,211	5,835	7,046	675
Foundries and plants of other manufacturers:						
Unalloyed nickel	r 7,136	15,731	1,300	13,453	14,753	8,114
Monel metal	129	812	100	730	830	111
Nickel silver [1]	3,328	10,314	9,406	57	9,463	4,179
Miscellaneous nickel alloys	47	442	25	383	408	81
Nickel residues	584	1,756	1,466	361	1,827	513
Total	r 7,896	18,741	2,891	14,927	17,818	8,819
Grand total:						
Unalloyed nickel	r 7,327	16,771	2,028	13,772	15,800	8,298
Monel metal	510	2,491	579	1,907	2,486	515
Nickel silver [1]	4,053	14,503	9,773	3,766	13,539	5,017
Miscellaneous nickel alloys	61	4,742	29	4,686	4,715	88
Nickel residues	671	1,785	1,466	397	1,863	593
Total	r 8,569	25,789	4,102	20,762	24,864	9,494

r Revised.

[1] Excluded from totals because it is copper-base scrap, although it contains considerable nickel.

CONSUMPTION AND USES

The consumption of nickel increased 18 percent, ferrous alloys accounting for most of the gain; use in stainless steel was up 41 percent, and in other steels and cast iron, up 25 and 12 percent, respectively.

TABLE 5.—Nickel (exclusive of scrap) consumed in the United States, by forms

(Short tons)

Form	1955-59 (average)	1960	1961	1962	1963	1964
Metal	84,809	87,399	101,394	103,485	110,365	123,443
Oxide powder and oxide sinter	18,058	19,392	15,883	13,760	12,461	21,090
Matte	6,070	17	16	3	2	2
Salts [1]	1,427	1,351	1,222	1,429	1,650	2,385
Total	110,364	108,159	118,515	118,677	124,478	146,920

[1] Figures do not cover all consumers.

TABLE 6.—Nickel (exclusive of scrap) consumed in the United States, by uses

(Short tons)

Use	1955-59 (average)	1960	1961	1962	1963	1964
Ferrous:						
Stainless steels	28,335	30,086	34,213	29,711	34,140	48,301
Other steels	17,025	15,331	18,238	18,608	19,727	24,679
Cast irons	5,098	4,605	4,649	5,503	5,901	6,605
Nonferrous [1]	28,461	26,567	28,789	28,215	24,794	23,639
High-temperature and electrical-resistance alloys	9,566	10,095	11,294	12,862	13,505	15,291
Electroplating:						
Anodes [2]	15,254	15,847	15,737	16,953	18,621	19,446
Solutions [3]	1,036	970	770	904	1,050	1,645
Catalysts	1,703	1,545	1,519	1,566	1,613	2,167
Ceramics	386	365	366	439	554	529
Magnets	876	778	773	910	777	664
Other	2,624	1,970	2,167	3,006	3,796	3,954
Total	110,364	108,159	118,515	118,677	124,478	146,920

[1] Comprises copper-nickel alloys, nickel silver, brass, bronze, beryllium alloys, magnesium and aluminum alloys, Monel, Inconel, and malleable nickel.

[2] Figures represent quantity of nickel used for production of anodes, plus cathodes used as anodes in plating operations.

[3] Figures do not cover all consumers.

TABLE 7.—Nickel (exclusive of scrap) in consumer stocks in the United States, by forms

(Short tons)

Form	1962	1963	1964
Metal	12,477	15,575	14,780
Oxide powder and oxide sinter	783	1,395	2,049
Matte	9	6	4
Salts	181	215	243
Total	13,450	17,191	17,076

PRICES

Nickel prices throughout the year were those which became effective May 24, 1962. The following prices, which include U.S. import duty, where applicable:

	Cents
Inco, electrolytic, f.o.b. Port Colborne, Ontario	79
Falconbridge, electrolytic, f.o.b. Thorold, Ontario	79
Sherritt Gordon, briquets, f.o.b. Port Colborne, Ontario, or Fort Saskatchewan, Alberta	79
Sherrit Gordon, powder, Niagara Falls, Ontario:	
Grades C and F	84
Grade S	79
Le Nickel, rondelles, at New York, and with freight equal Port Colborne, Ontario	79
Hanna, nickel in ferronickel (no charge for 45 percent iron), Riddle, Oreg., with freight equaled oxide sinter	75.25
Nickel oxide sinter, at Buffalo, N.Y., or other established U.S. points of entry, on nickel plus cobalt content	75.25

FOREIGN TRADE

Imports.—Virtually all U.S. nickel imports originated in Canada, 90 percent coming directly, 9 percent by way of Norway. and 1 percent by way of the United Kingdom. About 900 tons came from New Caledonia by way of France.

Exports.—Japan took 73 percent of the scrap exported and 57 percent of the total exports. Canada and Italy took 12 and 6 percent, respectively, of our scrap exports, and the United Kingdom and Sweden each took 2 percent. Of our total nickel exports, Canada took 14 percent; the United Kingdom, 7 percent; Italy, 5 percent; Federal Republic of Germany and Sweden, 4 percent each.

Tariff.—There was no change in the U.S. import duty of 1.25 cents per pound of gross weight on refined unwrought nickel, nickel powder, and ferronickel alloy; nickel ore, oxide powder and oxide sinter, matte, slurry, and residues continued to enter duty free.

TABLE 8.—U.S. imports for consumption of nickel products, by classes

(Short tons)

Class	1955-59 (average)	1960	1961	1962	1963	1964
Ore and matte	8,746	184	(1)	14	34	----------
Metal (pigs, ingots, shot, cathodes, etc.) [2]	92,281	79,662	115,985	115,972	108,127	104,627
Oxide powder and oxide sinter	[3] 32,523	[3] 24,584	14,613	8,661	12,887	16,862
Slurry [4]	270	4,477	258	406	[r] 1,716	15,483
Refinery residues [5]	449	----------	----------	----------	----------	----------
Scrap [2]	568	135	278	601	703	1,343
Total: Gross weight	134,837	109,042	131,134	125,654	[r] 123,467	138,315
Nickel content (estimated)	125,400	103,000	127,000	123,000	119,000	129,000

[r] Revised.

[1] Less than ½ unit.

[2] Separation of metal from scrap on basis of unpublished tabulations.

[3] Adjusted by Bureau of Mines.

[4] Nickel-containing material in powders, slurry, or any form, derived from ore by chemical, physical, or any other means, and requiring further processing to recover nickel or other metals.

[5] Reported to Bureau of Mines by importers.

Source: Bureau of the Census.

TABLE 9.—U.S. imports for consumption of new nickel products, by countries

(Short tons)

Country	Metal		Oxide powder and oxide sinter		Slurry and other[1]				Ore and matte	
	1963	1964	1963[2]	1964	1963		1964		1963[3]	
	Gross weight	Gross weight	Gross weight	Gross weight	Gross weight	Nickel content	Gross weight	Nickel content	Gross weight	Nickel Content
North America:										
Canada	98,319	91,813	12,191	16,153	r 1,603	r 604	15,433	11,135	1	(4)
Dominican Republic							25	15		
Total	98,319	91,813	12,191	16,153	r 1,603	r 604	15,458	11,150	1	(4)
South America:										
Brazil	1									
Colombia									33	1
Total	1								33	1
Europe:										
Denmark		54								
France	1,006	279	696	709						
Germany, West	19	4			3	2	25	5		
Greece					109	5				
Netherlands	15	(4)								
Norway	8,277	11,298			1	(4)				
United Kingdom	477	1,179		(4)					(4)	(4)
Total	9,794	12,814	696	709	113	7	25	5	(4)	(4)
Asia: Japan			(4)							
Oceania: French Pacific Islands	13									
Grand total	108,127	104,627	12,887	16,862	r 1,716	r 611	15,483	11,155	34	1

r Revised.

[1] Nickel-containing material in powder, slurry, or any form, derived from ore by chemical, physical, or any other means, and requiring further processing to recover nickel or other metals.

[2] Effective Sept. 1, 1963, content of nickel no longer reported. Bureau of Mines estimates 9,901 short tons nickel content in 1963.

[3] No transactions in 1964.

[4] Less than ½ unit.

Source: Bureau of the Census.

TABLE 10.—U.S. exports of nickel products, by classes

Class	1962		1963		1964	
	Short tons	Value	Short tons	Value	Short tons	Value
Ore, concentrates, and matte	45	$15,923	12	$4,976	8	$2,660
Nickel and nickel-alloy metals in ingots, bars, rods, sheets, plates, strips, and other crude forms	7,990	16,494,663	9,991	17,158,703	11,940	21,641,981
Nickel and nickel-alloy metal scrap	17,520	4,301,446	49,116	10,120,194	54,168	13,769,561
Nickel and nickel-alloy semifabricated forms, not elsewhere classified	803	3,462,592	714	3,198,688	939	4,754,391
Nickel-chrome electric-resistance wire except insulated	190	965,478	189	953,154	445	1,928,864
Nickel catalysts	1,093	1,963,293	905	1,748,599	1,002	2,013,287
Total	27,641	27,203,395	60,927	33,184,314	68,502	44,110,744

Source: Bureau of the Census.

TABLE 11.—World production of nickel by countries[1]

(Short tons)

Country	1955-59 (average)	1960	1961	1962	1963	[p] 1964
North America:						
Canada [2]	173,503	214,506	232,991	232,242	219,941	233,153
Cuba:						
Content of oxide	18,574	[3] 12,547	[e] 16,320	[e] 16,222	[e] 16,200	[e] 16,300
Estimated content of sulfide	[4] 198	1,600	----------	2,080	2,200	2,400
United States:						
Byproduct of copper refining	514	623	625	648	707	949
Recovered nickel in domestic ore refined	8,275	11,907	10,551	10,569	10,725	11,236
Total	201,064	241,183	260,487	261,761	249,773	264,038
South America:						
Brazil (content of ferronickel)	75	105	99	265	1,135	[e] 1,100
Venezuela (content of ore)	24	14	----------	----------	----------	----------
Total	99	119	99	265	1,135	[e] 1,100
Europe:						
Albania (content of nickeliferous ore) [e]	[5] 1,400	2,700	3,900	4,600	3,300	3,900
Finland:						
Content of nickel sulfate	121	126	177	179	172	[e] 175
Content of concentrates	[4] 324	2,369	2,239	2,715	3,230	[e] 3,200
Germany, East (content of ore) [e]	110	110	110	110	110	110
Greece (content of nickeliferous ore)	[6] 432	----------	----------	----------	----------	----------
Poland (content of ore)	1,317	1,382	1,453	1,458	[e] 1,400	[e] 1,400
U.S.S.R. (content of ore) [e]	54,000	58,000	77,000	90,000	90,000	90,000
Total [e]	57,700	64,700	84,900	99,100	98,200	98,800
Asia:						
Burma (content of speiss)	148	81	112	182	112	[e] 70
Indonesia (content of ore)	[4] 237	440	695	490	1,764	[7] 1,764
Total	385	521	807	672	1,876	1,834
Africa:						
Morocco (content of cobalt ore)	175	280	284	316	302	336
South Africa, Republic of (content of matte and refined nickel)	2,970	[e] 3,300	[e] 2,900	[e] 2,700	[e] 2,700	[e] 2,700
Southern Rhodesia (content of ore)	26	24	64	86	131	191
Total	3,171	[e] 3,600	[e] 3,250	[e] 3,100	[e] 3,130	[e] 3,230
Oceania: New Caledonia (recoverable)[8]	23,413	43,325	48,600	28,775	[e] 41,200	[e] 58,200
World total (estimate)	286,000	353,000	398,000	394,000	395,000	427,000

[e] Estimate. [p] Preliminary.

[1] This table incorporates some revisions.

[2] Comprises refined nickel and nickel in oxide produced and recoverable nickel in matte exported.

[3] Exclusive of unknown tonnage produced and stored at Nicaro since Sept. 20, 1960.

[4] 1 year only, as 1959 was the first year of commercial production.

[5] Average annual production 1958-59.

[6] Average annual production 1956-59.

[7] 1963 data.

[8] Comprises nickel content of matte and ferronickel produced in New Caledonia plus estimate of recoverable nickel in ore exported. Mine production (nickel content of ore) was as follows: 1955-59 (average) 31,900 tons; 1960, 59,000 tons; 1961, 58,800 tons; 1962, 37,500 tons; 1963, 48,800 tons; and 1964, estimated 65,300 tons.

WORLD REVIEW

NORTH AMERICA

Canada.—Canada produced 233,000 tons of nickel in 1964, regaining the level attained in 1961 before deliveries to the U.S. stockpiles were completed. Sales exceeded production by over 40,000 tons. Canadian smelter capacity was about 280,000 tons per year. Proven reserves have been maintained by exploratory drilling in known deposits and by drilling anomalies revealed by routine airborne geophysical exploration. Sherritt Gordon Mines Ltd. has assured its supply of feed by contracting for matte from New Caledonia to supplement its concentrate from Lynn Lake. The International Nickel Co. of Canada, Ltd. (Inco), and Falconbridge Nickel Mines Ltd. pursued aggressive policies of exploration in Canada and in the South Pacific, Africa, and the subtropics of North and South America where huge laterite and silicate deposits make up the greatest known world reserve of nickel.

Deliveries of Inco have increased steadily from a low of 159,000 tons in 1962 to 175,000 tons in 1963 and 222,000 tons in 1964. Inco mined 16.4 million tons of ore in 1964 compared with 13.6 million tons in 1963. At Crean Hill, Inco's seventh producing mine, output reached the planned 3,000 tons of ore per day. An internal shaft at the Murray mine was completed to 1,170 feet below the 3,000 level. Drifting at a number of levels was begun at the Copper Cliff North mine. A modified mining method, combining both blast hole and cut-and-fill techniques, was studied with a view of using it at the Frood and Levack mines. Depth problems were studied at the Creighton mine. With one blast, probably the largest ever in underground mining, 3.5 million tons of ore at the Stobie mine was loosened for removal. Development of the Birchtree mine in Manitoba was begun. Underground development of Inco's mines reached a cumulative total of 565 miles. The ore reserve at yearend was 304 million tons.

At Copper Cliff, Inco increased the efficiency of the smelter by raising its oxygen production capacity to 1,000 tons per day. Underway was the construction of a plant to produce Nickel Oxide Sinter 90, designed to supplant, in part, Nickel Oxide Sinter 75. The newly enlarged iron ore plant at Copper Cliff went into full-scale operation, using supplemental feed of pyrrhotite from newly installed facilities at the Levack mill.[2]

On October 29, Inco dedicated its large Paul D. Merica Research Laboratory, in Sterling Forest, N.Y. The company's research effort emphasized the development of new alloys and determination of factors which control properties of alloys. The former laboratory at Bayonne, N.J., was closed.[3]

Falconbridge Nickel Mines Ltd. made record deliveries of nickel in 1964, 47 percent more than in 1963, drawing upon reserves of unfinished nickel to augment decreased smelter production of matte. Sales were about 39,000 tons, 6,000 tons above production. The proven reserve of ore at the end of the year was put at 52 million tons containing 1.43 percent nickel compared with 51 million tons of 1.42 percent ore at the beginning of the year. The proven reserve at the Strathcona mine was extended, and a new orebody, known as the North mine, was discovered southeast of the Fecunis mine. The company reported exploration in the Sudbury area, Manitabo, in Ungava, and in the Abitibi Peridotite Belts of Ontario and Quebec. At Maimon in the Dominican Republic, Falconbridge operated a plant with a capacity of 1 ton of ferronickel per day and was considering an $80 million plant to produce 50 tons per day.[4]

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[2] The International Nickel Co. of Canada, Ltd. Annual Report. 1964, 39 pp.

[3] Wingate, Henry S. Intensifying the Search. Inco Magazine, v. 29, No. 4, winter 1964–65, pp. 2–6.

[4] Falconbridge Nickel Mines Ltd. Annual Report. 1964, 33 pp.

Sherritt Gordon Mines Ltd. produced 14,000 tons of nickel, up from 10,500 tons in 1963. Sales exceeded production by about 300 tons. It sold 110 million pure nickel coin blanks to the Republic of South Africa. Airborne and ground geophysical exploration supported by drilling has been pressed in an effort to increase the supply of concentrate for its plant at Fort Saskatchewan. Scarce supply has limited Sherritt's sales of nickel. An oilfield rig was brought to Lynn Lake to sink a 12-inch hole to a depth of 3,000 feet. The top 2,000 feet will be reamed to a 4-foot smooth-wall ventilating shaft, and the bottom 1,000 feet will be enlarged to become a service shaft.[5]

Marbridge Mines Ltd., owned jointly by Falconbridge Nickel Mines Ltd. and Marchant Mining Co., continued to produce about 400 tons of ore daily from its mine near Malartic, Quebec.[6] Concentrate was sold to Falconbridge. Drilling outlined a new orebody south of the present No. 1 mine. A headframe was erected preparatory to sinking a shaft into the new No. 2 orebody, which contains an indicated 125,000 tons of 3.50 percent nickel ore. The No. 1 orebody reserve was 110,000 tons of ore containing 1.90 percent nickel.

McWatters Gold Mines Ltd. sank three drill holes on its property in Langmuir Township, near Timmons, Ontario. One 400-foot core averaged 1.4 percent nickel, and another 295-foot core averaged 1.24 percent nickel.

Giant Mascot Mines Ltd. treated 325,000 tons of ore and recovered 1,980 tons of nickel in a concentrate which was shipped to Japan. The ore reserve was maintained, and two new ore zones were discovered in the mine which is 12 miles northeast of Hope, British Columbia. The contract to ship concentrate to the Sumitomo Metal Mining Co. of Japan continues in effect through 1966.[7]

The Lorraine Mining Co., Ltd., a subsidiary of McIntyre Porcupine Mines, Ltd., completed a 400-ton-per-day mill at its copper-nickel property in the Belleterre area and started operation in December. Concentrates are shipped by truck and rail to Inco's smelter at Copper Cliff. The reserve was reported to be about 550,000 tons with 1.57 percent copper, 0.63 percent nickel, and some precious metals.[8]

Raglan Nickel Mines Ltd. continued to diamond drill at its Raglan Lake property, Cape Smith belt, in the northern Ungava Peninsula of Quebec.[9] One core contained a 58-foot section averaging 9.06 percent nickel and 1.08 percent copper. Drilling continued into the winter.

Metal Mines Ltd., a subsidiary of the Canadian Faraday Corp., Ltd., shipped nickel-copper concentrates from its mine at Gordon Lake, Ontario, to Inco at Copper Cliff, Ontario, for smelting. Ore production remained below capacity, owing partly to shortage of miners.[10]

Cuba.—In February 1964 a Soviet metallurgist was reported to be in Cuba to survey plans for a new nickel plant in Oriente Province. The two large nickel operations seized in 1960 continue to operate well below designed capacity.

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[5] Sherritt Gordon Mines Ltd. Annual Report. 1964, 16 pp.

[6] Northern Miner (Toronto). Marbridge To Sink a Second Shaft Boost Milling Rate. V. 50, No. 34, Nov. 12, 1964, pp. 1, 10.

[7] Giant Mascot Mines Ltd. Annual Report. 1964, 12 pp.

[8] McIntyre Porcupine Mines, Ltd. Annual Report. 1964, p. 6.

[9] Northern Miner (Toronto). Four Drills Busy Extending Zone at Raglan Nickel. V. 50, No. 28, Oct. 1, 1964, p. 12.

[10] Canadian Faraday Corp., Ltd. Annual Report. 1964, 8 pp.

In March 1964, Freeport Sulphur Co. reported settlement of claims against it for indebtedness of subsidiary companies which controlled the nickel operations at Moa Bay and a refinery in Louisiana. Total indebtedness was over $100 million, including over $60 million in bank loans.

SOUTH AMERICA

Brazil.—The producing companies in Brazil were Morro do Niquel, S.A., an affiliate of Société Le Nickel, and Cia. Niquel do Brasil, both making ferronickel.

Venezuela.—On November 4, 1964, the Supreme Court upheld the 1960 action of the Ministry of Mines and Hydrocarbons which canceled nickel concessions held by Cia. Meridional de Minas, S.A., a subsidiary of Inco. The ministry had contended that the concessions, in the State of Aragua, were not fully exploited in accordance with the law.[11]

EUROPE

Albania.—Production of ferronickel increased. Ore production from the Pishkash and Cervenaka iron-nickel deposits was about 350,000 tons.

Czechoslovakia.—A plant at Sered processed low-grade oxide ores to recover nickel as carbonate; this intermediate product was converted to sulfate and electrolyzed to produce electrolytic nickel.[12]

Finland.—Outokumpu Oy produced electrolytic nickel at Harjavalta using concentrate from Kotalahti, central Finland. The nickel smelting and refining process was described in a technical article.[13]

In 1963, 3,230 tons of electrolytic nickel was produced, 2,482 tons exported, and 277 tons (gross weight) of metal, alloys, semimanufactures, and manufactures imported. In 1964 production was 3,200 tons electrolytic nickel and 175 tons nickel in sulfate. Exports were 3,496 tons and imports 456 tons (gross weight). Ore deposits discovered by the Finnish Geological Research Institute at Nivala were reported to contain 5 million tons of ore averaging 0.70 percent nickel and 0.26 percent copper.[14]

Norway.—Production of nickel at the Falconbridge Nikkelverk A/S, Kristiansand South, increased 11 percent over 1963.[15]

United Kingdom.—The International Nickel Co. (Mond), Ltd., consolidated rolling mill operations at Hereford and enlarged its research laboratory at Birmingham. The company announced plans to modernize its carbonyl process nickel refinery at Clydach, Wales. An estimated $8 million will be spent; the project is scheduled for completion by mid-1966.[16]

U.S.S.R.—New nickel-bearing deposits in the Noril'sk area were reported. A gas pipeline was being laid from Siberia into the region. In the south Ural region an integrated nickel operation has been built at Orenburg.

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[11] Bureau of Mines. Mineral Trade Notes. V. 60, No. 2, February 1965, p. 29.

[12] Engineering and Mining Journal. Czech Nickel Plant Uses Cuban Process. V. 165, No. 1, January 1964, p. 82.

[13] Toivanen, Toivo, and Per Olov Grönqvist. Nickel Refining in Finland. Canadian Mining and Metallurgical Bulletin (Montreal), v. 57, No. 626, June 1964, pp. 653–658.

[14] Metal Bulletin (London). Finnish Ore Deposits. No. 4887, Apr. 10, 1964, p. 21.

[15] P. 9 of work cited in footnote 4.

[16] Pp. 20 and 23 of work cited in footnote 2.

Yugoslavia.—Nickel deposits discovered near Pristina, Serbia, were reported to contain 3.5 million tons averaging 1.5 percent nickel. Mining is expected to be at the yearly rate of 2,000 tons contained nickel. A ferronickel plant will be constructed near Skopje.[17]

ASIA

Indonesia.—It was reported that the Government and Japanese concerns would jointly develop projects in Pomalaa and the islands of Maniang and Lomo, south Sulawesi. Reserves are estimated at 5 to 6 million tons containing 3 percent nickel in Pomalaa, 190,000 tons on Maniang, and 100,000 tons on Lomo.[18] With ore production scheduled at 14,000 tons a month, the latter two deposits were to be mined out by yearend.[19] Pomalaa deposits were to be mined at the rate of 10,000 tons a month.[20] Deposits at Soroaki, Malili, central Sulawesi, were to be developed.[21]

Japan.—The nickel industry was dependent essentially upon imports to supply raw materials. Since 1961 proportionately less ore and concentrate, and more matte, has been imported. Some New Caledonian ferronickel was imported in competition with Japanese-produced ferronickel. In addition to long-term contracts for New Caledonian ore, a group of Japanese companies has reached agreements with Indonesian authorities to mine in Sulawesi. In the near future, nickel oxide also may be imported in large amounts for use in steels and alloys.

Philippines.—Kaiser Aluminum & Chemical Corp., and also Japanese firms were reported to be considering development of lateritic deposits on Mindanao Island. The nickel law was amended to create more favorable conditions for possible investors.

AFRICA

South Africa, Republic of.—Kashane Exploration Ltd., jointly owned by Anglo-American Corp. and Inco, carried on an exploration program in the area of the Pilandsberg nickel mine; some drilling was reported.

Southern Rhodesia.—The Trojan mine, near Bindura, went into production at the end of 1964. Ore, grading over 1.5 percent nickel, was mined at about 130 tons per day, concentrated to 15 to 18 percent nickel, and bagged for shipment. Mineralization is in an area of ultrabasic rocks and consists of intergrowths of nickel minerals pentlandite and millerite with magnetite, pyrrhotite, and chalcopyrite.[22]

OCEANIA

Australia.—Inco's subsidiary Southern Mining & Development Co., Ltd., was granted a 1-year concession to prospect in the area between Salamaua and Garaina in the Morobe District, Territory of Papua and New Guinea.[23]

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[17] Metal Bulletin (London). Skopje Ferro-Nickel Plant Planned. No. 4959, Dec. 24, 1964, p. 20.

[18] Mining Journal (London). Copper and Nickel Exploration. V. 262, No. 6703, Feb. 7, 1964, p. 96.

[19] World Mining. V. 17, No. 9, August 1964, p. 76.

[20] Bureau of Mines. Mineral Trade Notes. V. 59, No. 3, September 1964, p. 49.

[21] World Mining. V. 17, No. 11, October 1964, p. 95.

[22] Mining Magazine (London). Rhodesian Nickel Producer. V. 112, No. 3, March 1965, pp. 205, 207.

[23] Metal Industry (London). New Guinea Nickel. V. 105, No. 1, July 2, 1964, p. 9.

New Caledonia.—The Société Le Nickel announced plans to double annual capacity to about 55,000 tons of nickel by 1969. This would involve further expansion and modernization of the Doniambo plant and the opening of new mines at Poro and Nepoui. To mine lower grade ore (2.6–2.8 percent nickel) and thus extend the reserve, the company sought certain economic arrangements with the Government; these included reduction in import duties on needed equipment and assurances of stable taxes for 17 years.[24]

Solomon Islands.—Inco held a concession to prospect for nickel in in the islands.

TECHNOLOGY

A method was developed for recovering 90 percent of the nickel and cobalt contained in high-temperature, high-strength alloy scrap.[25] Within limits, the replacement of nickel by cobalt in types 302 and 309 stainless steel had little effect on their physical properties.[26]

Research was described on the activity of copper and nickel in molten copper-nickel alloys,[27] the heat capacity and entropy of nickel sulfide,[28] and the five phases in the nickel-gladolinium system.[29] A Geological Survey author described the nickeliferous laterites in Oregon and California.[30]

A method, purported to exploit at a profit isolated copper-nickel sulfide deposits, combines flotation, a sulfatizing roast, a water leach, and a separation of the copper and nickel with an organic solvent.[31]

Industrial developments comprise nickel-base alloy strip for magnetic applications, protective coatings of stainless-steel flake applied to steel, and nickel-iron coatings for nonmetallic substrates. The use of nickel-powder slurry to coat mild steel strip is being studied. Powder compacts of 99.9 percent pure nickel agglomerates have been made with a porosity of nearly 90 percent. They show uniformly low radial and axial shrinkage and can be produced with controlled pore size and distribution.[32]

Sherritt Gordon Mines Ltd. research developed a new method to produce dispersion-strengthened nickel and its alloys, imparting excellent high-temperature properties. Enough data on the treatment of laterite was collected to permit the company to design a large-scale demonstration plant. Composite and monocomponent powders are being developed. A nickel-aluminum powder for flame spraying was produced in commercial quantities throughout the year. A method to prepare nickel sulfamate solutions from powder was put in operation for electroplating and electroforming operations. See work cited in footnote 5.

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[24] Mining Journal (London). New Caledonian Nickel Expansion. V. 263, No. 6747, Dec. 11, 1964, p. 451.

[25] Hayashi, Masami, Donald R. Peterson, and D. W. Bridges. Electrochemical Recovery of Cobalt-Nickel Alloy From Superalloy Scrap. BuMines Rept. of Inv. 6445, 1964, 35 pp.

[26] Tilman, M. M. Effects of Substituting Cobalt for Nickel on the Tensile Properties and Hardness of Two Types of Stainless Steel. BuMines Rept. of Inv. 6427, 1964, 16 pp.

[27] Schultz, C. W., G. R. Zellars, S. L. Payne, and E. F. Foerster. Activities of Copper and Nickel in Liquid Cooper-Nickel Alloys. BuMines Rept. of Inv. 6410, 1964, 9 pp.

[28] Weller, W. W., and K. K. Kelley. Low-Temperature Heat Capacities and Entropies at 298.15° K of Sulfides of Arsenic, Germanium, and Nickel. BuMines Rept. of Inv. 6511, 1964, 7 pp.

[29] Copeland, M. I., M. Krug, C. E. Armantrout, and H. Kato. Nickel-Gadolinium Phase Diagram. BuMines Rept. of Inv. 6566, 1964, 24 pp.

[30] Hotz, Preston E. Nickeliferous Laterites in Southwestern Oregon and Northwestern California. Econ. Geol., v. 59, No. 3, May 1964, pp. 355–396.

[31] Mining Magazine (London). Copper-Nickel Ores in Isolated Locations. V. 110, No. 6, June 1964, pp. 414–415.

[32] Sherritt Gordon Mines Ltd. New Low-Density Pure Nickel Powder Developed for Powder Metallurgy. News Release No. 9S–4403, May 25, 1964.

The reason for thoria dispersed (TD) strengthening of nickel was determined to be the result of stored energy developed by thermal and mechanical treatment.[33] Annealing TD-nickel at 1,100° F (600° C) softens it, but annealing at 1,100° F to 2,650° F (600° C to 1,400° C) hardens it.[34] Usable structural strengths of TD-nickel were measured up to 2,500° F (1,370° C).[35] Small tubing is now being drawn of TD-nickel. In the range 1,900° F to 2,300° F, it has mechanical properties superior to many nickel and cobalt-base superalloys.[36]

It was discovered that sigma-phase embrittlement of nickel-base superalloys could be prevented by minor adjustments in their composition to reduce the average number of electron vacancies per atom to less than 2.32. Increased rupture life and increased creep strength were noted in the test alloys. These properties prolong the life of turbine blades under the severe temperature and stress in gas turbines.[37] It has been determined that the thermal endurance of a number of wrought high-temperature alloys decreases rapidly in a heating-cooling cycle as the maximum temperature approaches 1,000° C, but that it increases when the maximum is above 1,000° C. Retention of strength and ductility at high-temperatures is essential to resistance to thermal fatigue.[38]

A low-cost high-iron (65 percent) alloy has been developed for use in gas turbines.[39] A series of alloys containing about 70 percent nickel has been developed with low-temperature ductility as well as high-temperature strength.[40]

An acid-resistant alloy has been formulated by modifying chromium-nickel stainless steel with admixtures of other constituents, chief of which are molybdenum and silicon.[41]

Newer techniques and new filler metals have been developed to make welds with physical and mechanical properties which match those of the nickel-iron alloys used in cryogenic service.[42] In a burst test on a cylinder made of 9 percent nickel steel, failure occurred at 6½ times the design pressure and in a ductile manner, demonstrating the suitability of the material for cryogenic use.[43]

Maraging steel billets with 12-inch-square cross sections have been reduced without loss of their transverse properties. Previously the limit was a cross section of 2 inches by 4 inches.[44]

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[33] White, J. E., and R. D. Carnahan. A Microplasticity Study of Dispersion Strengthening in TD-Nickel. Trans. AIME (Met. Soc.), v. 230, No. 6, October 1964, pp. 1298–1306.

[34] Metal Progress. Recrystallization in Dispersion Hardened Nickel. V. 86, No. 5, November 1964, pp. 173–175.

[35] Metal Progress. Dispersion Strengthened Nickel—Its Properties. V. 85, No. 6, June 1964, pp. 182, 184.

[36] Missiles and Rockets. Superior Markets TD Nickel Tubing. V. 14, No. 9, Mar. 2, 1964. p. 23.

[37] Boesch, William J., and John S. Slaney. Preventing Sigma Phase Embrittlement in Nickel Base Superalloys. Metal Prog., v. 86, No. 1, July 1964, pp. 109–111.

[38] Franklin, A. W., J. Heslop, and R. A. Smith. Some Metallurgical Factors Influencing the Thermal-Fatigue Resistance of Wrought Nickel-Chromium-Base High-Temperature Alloys. J. Inst. Metals (London), v. 92. pt. 10, June 1964, pp. 313–322.

[39] Chemical and Engineering News. V. 42, No. 3, Jan. 20, 1964, p. 35.

[40] Freche, John C., and William J. Waters. High Temperature Service Offered by New Nickel-Base Alloys. Foundry, v. 92, No. 7, July 1964, pp. 44–47.

[41] Tsukamoto, F. A Japanese Stainless Steel With Acid Resistance. Metal Prog., v. 85, No. 1, January 1964, pp. 107–108.

[42] Flannery, J. W., and C. E. Witherell. Welding 3½ and 9 Percent Nickel Steels and 36 Percent Nickel-Iron Alloy for Cryogenic Service. Mat. Res. & Standards, v. 4, No. 10, October 1964, pp. 533–539.

[43] Chemical Age (London). Demonstration of 9 Percent Nickel Steel at Low Temperatures. V. 92, No. 2349, July 18, 1964, p. 104.

[44] Product Engineering. Steel—Large and Tough. V. 35, No. 10, May 11, 1964, p. 51.

Hot stage studies of the austenite-to-martensite transformation in 18-percent-nickel maraging steels show that the martensite forms slowly as the temperature drops below 400° F. The transformation is virtually complete at about 300° F. Tests show that welded maraging steel parts require conventional treatment to develop optimum strength.[45]

Sulfamate solutions have been formulated from which nickel may be electrodeposited at the high rate of 0.02 inch in an hour. The hardness of the deposits may be controlled by altering the speed of deposition.[46]

Nickel-plating speeds have been increased 50 times by contouring the anodes to the parts to be plated and pumping hot electrolyte through the space between parts and anodes. Uniform coverage is an added bonus.[47] Microporosity has been introduced in bright nickel electrodeposits by including submicron-size nonmetallic particles in the electrolyte. Chromium, deposited over the porous deposit, approaches stainless steel in corrosion resistance.[48]

A soft magnetic alloy of 50 percent nickel and 50 percent iron has been developed for electronic transformers.[49] Nickel alkyl phosphates have been found to combat knock in automotive engines.[50]

Patents were issued on virtually all categories of application in the technology of nickel, including recovery of nickel from ores,[51] composition of alloys,[52] electrodeposition,[53] electroless deposition,[54] catalyses,[55] chemical reactions,[56] magnetic films,[57] brazing,[58] and electronics.[59]

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Kohn, Marvin L., and Charles D. Schaper. Welding 18 Percent Ni Maraging Steel by Electron Beam. Metal Prog., v. 85, No. 5, May 1964, pp. 93–94.

[46] Metal Industry (London). High Speed Nickel Solution Permits Control of Stress in Deposits. V. 104, No. 20, May 14, 1964, p. 648.

[47] Sandford, J. E. Ultrafast Plating Covers Contours. Iron Age, v. 194, No. 12, Sept. 17, 1964, pp. 77–79.

[48] Barnett, Richard K. New Nickel Plating Process for Improved Corrosion Resistance. Metal Prog., v. 85, No. 6, June 1964, pp. 87–90.

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[49] Iron Age. Magnetic Alloy. V. 194, No. 5, July 30, 1964, p. 68.

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[52] Copson, Harry R., and Frances S. Lang (assigned to The International Nickel Co., Inc., New York). Austenitic Chromium-Nickel Stainless Steels Resistant to Stress-Corrosion Cracking. U.S. Pat. 3,159,479, Dec. 1, 1964.

[53] Kardos, Otto, and William B. Stoddard, Jr. (assigned to Hanson-Van Winkle-Munning Co., New Jersey). Electrodeposition of Nickel. U.S. Pat. 3,152,975, Oct. 13, 1964.

[54] West, Harry J., and Richard F. Gieselman (assigned to Westinghouse Electric Corp., East Pittsburgh, Pa.). Electroless Deposition of Nickel. U.S. Pat. 3,148,072, Sept. 8, 1964.

[55] Silverman, Morris (assigned to California Research Corp., San Francisco, Calif.). Processed for Increasing the Hydrocracking and Hydrogenating Activity of a Supported Nickel Catalyst Using Phosphine. U.S. Pat. 3,144,415, Aug. 11, 1964.

[56] Schlain, David, and Charles B. Kenahan (assigned to the Secretary of the Interior). Activation of Inert or Passive Metals. U.S. Pat. 3,117,000, Jan. 7, 1964.

[57] Chu, William W. L., and Bernard C. Wagner (assigned to General Electric Co., New York). Thin Magnetic Films. U.S. Pat. 3,117,896, Jan. 14, 1964.

[58] Cape, Arthur T. (assigned to Coast Metals, Inc., Little Ferry, N.J.). Compositions for Brazing and Coating. U.S. Pat. 3,117,039, Jan. 7, 1964.

[59] Brodie, Ivor, and Gene R. Feaster (assigned to Westinghouse Electric Corp., East Pittsburgh, Pa.). Cathode. U.S. Pat. 3,148,056, Sept. 8, 1964.

Nitrogen

By Richard W. Lewis[1]

◆

DOMESTIC anhydrous ammonia production capacity continued to increase substantially with many new firms entering the industry and established firms expanding their facilities. At the beginning of the year, 1964, total ammonia capacity was estimated to be 8.2 million short tons. At yearend, a capacity of 9.4 million tons was indicated, an increase of 1.2 million tons or 15 percent. In addition, new facilities were under construction that would boost total capacity another 4 million tons by the end of 1966.

TABLE 1.—Salient statistics of the nitrogen industry

(Thousand short tons of contained nitrogen)

	1955-59 (average)	1960	1961	1962	1963	1964
United States:						
Production as ammonia	3,277	4,118	4,429	4,920	[r] 5,631	6,385
Production as high-purity nitrogen gas	264	725	1,045	1,683	[r] 1,992	2,213
Imports for consumption of nitrogen compounds	278	279	325	383	[r] 401	494
Exports of nitrogen compounds	247	211	173	246	219	337
Consumption [1]	3,244	[r] 4,914	[r] 5,130	[r] 4,849	[r] 5,545	6,283
World: Production [1]	10,948	14,184	15,403	16,320	[r] 18,745	21,067

[r] Revised.
[1] Estimate, exclude nitrogen gas.

DOMESTIC PRODUCTION

Optimism prevailed in the nitrogen compound producing industries and a large number of new production facilities were under construction while others were being planned. The output of nitrogen gas in 1964 increased 10 percent with a favorable outlook for continued heavy expansion.

The following anhydrous ammonia (NH_3) plants with estimated production capacities were reported completed during the year:

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[1] Commodity specialist, Division of Minerals.

Company	Plant location	Added NH_3 capacity (tons per year)
American Chemical Corp	Omaha, Nebr	100,000
Ammonia, Inc	Bonnie, Fla	53,000
California Ammonia Co	Lathrop, Calif	53,000
Central Nitrogen, Inc	Terre Haute, Ind	120,000
Columbia Nitrogen Corp	Augusta, Ga	125,000
E. I. du Pont de Nemours & Co., Inc	Victoria, Tex	100,000
Farmers Chemicals Association, Inc	Chattanooga, Tenn	35,000
J. R. Simplot Co	Pocatello, Idaho	53,000
Lone Star Producing Co	Kerens, Tex	115,000
Odessa Natural Gasoline Co	Odessa, Tex	21,000
Southern Farm Supply Asso	Plainview, Tex	21,000
Southwestern Nitrochemical Corp	Chandler, Ariz	14,000
Techne Corp	Plainview, Tex	21,000
Tenneco Chemical Co	Houston, Tex	120,000
Tuloma Gas Products Co	Texas City, Tex	210,000
Western Ammonia Corp	Dimmitt, Tex	27,000

Additional anhydrous ammonia facilities either under construction or in the planning stage in 1964 were as follows:

Company	Plant location	Added NH_3 capacity (tons per year)	Completion date
Air Products & Chemicals, Inc	New Orleans, La	400,000	1965
American Cyanamid Co	Fortier, La	350,000	(1)
Ammonia, Inc	Bonnie, Fla	53,000	1965
Apple River Chemical Co	E. Dubuque, Ill	350,000	1966
Arkla Chemical Co	Helena, Ark	210,000	1966
Coastal Chemical Corp	Yazoo City, Miss	350,000	1965
Collier Carbon & Chemical Corp	Brea, Calif	135,000	1965
Consumers Cooperative Association	Fort Dodge, Iowa	195,000	1965
Continental Oil Co	Blytheville, Ark	350,000	1965
The Dow Chemical Co	Freeport, Tex	42,000	(1)
Fel-Tex, Inc	Fremont, Nebr		
Frontier Chemical Co	Wichita, Kans		
Mississippi Chemical Corp	Yazoo City, Miss	35,000	1965
Monsanto Chemical Co	Luling, La	210,000	1965
Olin Mathieson Chemical Corp	Lake Charles, La	490,000	1965
Phillips Pacific Chemical Co	Kennewick, Wash	53,000	1965
Phillips Petroleum Co	Beatrice, Nebr	200,000	(1)
Reserve Oil & Gas Co	Hanford, Calif	23,000	1965
Shamrock Oil & Gas Co	McKee, Tex	55,000	1965
Shell Oil Co	Ventura, Calif	(1)	1965
Union Carbide Corp	Texas City, Tex	82,000	1965
United States Steel Corp	Clairton, Pa	400,000	1966
Valley Nitrogen Producers, Inc	Helm, Calif	125,000	(1)
W. R. Grace & Co	Memphis, Tenn	75,000	1965
Wycon Chemical Co	Cheyenne, Wyo	18,000	1965

[1] Not announced.

In the list above, the following companies were expanding the production capacities of existing facilities: Mississippi Chemical Corp., Monsanto Chemical Co., Phillips Pacific Chemical Co., Shamrock Oil & Gas Co., Shell Oil Co., and W. R. Grace & Co.

The Collier Carbon & Chemical Corp. plant under construction at Brea, Calif., was to have an annual capacity estimated at 260,000 tons, but would replace an old plant of 125,000 ton capacity.

John Deere Chemical Co. began producing urea at a new 250-ton-per-day plant at Pryor, Okla. Lone Star Producing Co. had a 260-ton-per-day plant under construction at Kerens, Tex. Columbia Nitrogen Corp. was building a 25,000-ton-per-year plant at Augusta, Ga. Firms reported planning new urea plants included: American

Cyanamid Co. at Fortier, La., Collier Carbon & Chemical Corp. at Brea, Calif., Olin Mathieson Chemical Corp. at Lake Charles, La., Shell Chemical Corp. at Ventura, Calif., and Valley Nitrogen Products, Inc. at Helm, Calif.

Carolina Nitrogen Co. at Wilmington, N.C. started producing nitrogenous fertilizers using ammonia supplied by W. R. Grace & Co. from its large plant in Trinidad. The plant at Wilmington included a nitric acid unit having a rated capacity of 380-tons-per-day.

Plans were announced for new nitric acid producing units to be constructed for American Cyanamid Co. at Hannibal, Mo., and Cominco Products, Inc. at Beatrice, Nebr., while Phillips Petroleum Co. had a 50-ton-per-day nitric acid plant under construction at Pasadena, Tex.

TABLE 2.—Nitrogen production in the United States

(Short tons of contained nitrogen)

	1960	1961	1962	1963 [r]	1964 [p]
Anhydrous ammonia: Synthetic plants [1]	3,962,272	4,282,160	4,778,106	5,479,080	6,217,621
Ammonia compounds, coking plants:					
Ammonia liquor	12,241	10,990	11,166	12,059	13,359
Ammonium sulfate	134,034	125,951	124,112	131,385	144,151
Ammonium phosphates	9,769	10,111	6,909	8,234	9,738
Total	4,118,316	4,429,212	4,920,293	5,630,758	6,384,869
Nitrogen gas [1]	724,724	1,045,357	1,682,643	1,992,112	2,212,816

[p] Preliminary. [r] Revised.

[1] Bureau of the Census Current Industrial Reports.

TABLE 3.—Major nitrogen compounds produced in the United States

(Thousand short tons, gross weight)

Compounds	1963 [r]	1964 [p]
Ammonium nitrate	3,960	4,375
Ammonium sulfate	1,794	2,294
Ammonium phosphate	2,635	3,096
Nitric acid	4,221	4,609
Urea	1,091	1,224

[p] Preliminary. [r] Revised.

Source: Bureau of the Census and U.S. Tariff Commission (urea only).

New air-separation plants were planned for producing oxygen and nitrogen (gas or liquid) for industrial use, others were under construction, and several were placed in operation. Most of these additions with estimated capacities are listed below:

Company	Plant location	Nitrogen capacity (tons per day)
Air Liquide Co. for Big Three Welding Equipment Co.	Beaumont, Tex. (contracted)	[1] 800
Air Products and Chemicals, Inc.	Lathrop, Calif. (on stream)	300
	Burns Harbor, Ind. (on stream)	500
	Sparrows Point, Md. (on stream)	450
	New Orleans, La. (under construction)	NA
Air Reduction Pacific Co.	Vancouver, Wash. (completed)	[1] 150
Air Reduction Sales Co.	Buffalo, N.Y. (contracted)	[1] 650
American Cryogenics, Inc.	Savannah, Ga. (planned)	[1] 400
Chemetron Corp. National Cylinder Gas Division.	Sharon, Pa. (planned)	[1] 355
	Cincinnati, Ohio (on stream)	NA
	Tampa, Fla. (under const.)	30
	Peoria, Ill. (under const.)	[1] 125
Union Carbide Corp., Linde Co.	Hamilton, Miss. (under const.)	NA
	Antioch, Calif. (on stream)	NA
	Gary, Ind. (planned)	[1] 2,400
	Cumberland, Md. (on stream)	25
	Texas City, Tex. (on stream)	450
	Fontana, Calif. (under const.)	[1] 400
	Keasbey, N.J. (planned)	[1] 450
	Cape Kennedy, Fla. (planned)	400

NA Not available.
[1] Oxygen and nitrogen.

CONSUMPTION AND USES

Estimated domestic consumption of nitrogen, as compounds, increased 13 percent over that of 1963. According to the Department of Agriculture's preliminary report, nitrogen consumed by agriculture as fertilizers for the year ending June 30, 1964 was 4,401,530 tons, 12 percent more than consumed in the 12-month period ending June 30, 1963.

Approximately 80 percent of all nitrogen consumed, excluding gas and liquid, went into fertilizer materials.

PRICES

Prices on fertilizer-grade anhydrous ammonia, ammonium nitrate, and urea were little changed from those in 1963 according to the Oil, Paint and Drug Reporter quotations. Domestic ammonium nitrate with dolomite and ammonium sulfate were $2 to $4 higher per ton. It was reported that imported anhydrous ammonia was offered at under $60 per ton on long term contracts in bulk, and that some of the large domestic producers were making similar offers.

TABLE 4.—Price quotations for major nitrogen compounds in 1964

(Per short ton)

Compound	Jan. 6	Dec. 30	Effective date of change
Ammonium nitrate, fertilizer grade, 33.5 percent N (nitrogen):			
Canadian carlots, f.o.b. shipping point, bags	$70.00	[1] $67.00	Dec. 7
Domestic, f.o.b. works, bags	70.00	[1] 67.00	Dec. 7
Ammonium nitrate, domestic with dolomite, 20.5 percent N, bags, carlots, Hopewell, Va	48.00	[2] 52.00	Nov. 9
Ammonium sulfate, standard granular, bulk, f.o.b. works	30.00	[3] 32.–34	Sept. 7
Anhydrous ammonia, fertilizer, tanks, works, freight equalized east of Rockies	92.00	[4] 92.00	Oct. 5
Cyanamide, fertilizer-mixing grade, 21 percent N, granular, bags, Niagara Falls, Ontario	59.00	(5)	
Sodium nitrate, domestic, commercial, bulk, carlots, works	44.00	44.00	
Sodium nitrate, imported, commercial, bulk, carlots, port warehouse	44.00	[6] 44.00	
Urea:			
Industrial, 46 percent N, bags, carlot, delivered, f.o.b. plant [7]	100.00	100.00	
Agricultural, 45 percent N, bags, carlot, delivered	96.00	[8] 92.00	Nov. 9

[1] Quoted at $65 per ton Sept. 7 to Nov. 9, and $68 from Nov. 9 to Dec. 7.
[2] Quoted at $49 per ton Sept. 7 to Nov. 9.
[3] Quoted at $30–31 per ton Feb. 10 to July 6, $32 to Sept. 7.
[4] Quoted at $84 Aug. 10 to Oct. 5.
[5] Not quoted after July 6.
[6] Quote changed to "Gulf wholesale" on Dec. 21.
[7] Quote changed from "f.o.b. plant" to "freight equalized" on Feb. 17.
[8] Quoted at $89 per ton Aug. 10 to Nov. 9.

FOREIGN TRADE

The gross weight of all nitrogen compounds imported for consumption was less than 0.5 percent greater than in 1963; however, the tonnage of nitrogen content was 23 percent greater due to heavy imports of anhydrous ammonia, chiefly from Trinidad. Incoming shipments of ammonium sulfate, ammonium phosphate, sodium nitrate, and urea were less than in 1963 by 11 percent, 26 percent, 12 percent, and 5 percent respectively. Other than anhydrous ammonia, ammonium nitrate, calcium nitrate, and nitrogen solutions were the only imported fertilizer items that were increased. Industrial ammonium nitrate imports were more than doubled in 1964, but the tonnage remained rather insignificant.

Total exports (gross weight) were increased 43 percent over the quantity exported in 1963. The major increase was in shipments of ammonium phosphate which was nearly double the tonnage shipped in 1963. Smaller tonnage increases were reported for anhydrous ammonia and ammonium nitrate, but the percentage increase over 1963 was a phenomenal 1,227 percent and 274 percent respectively.

TABLE 5.—U.S. imports for consumption and exports of major nitrogen compounds

(Short tons)

Compounds	1963		1964	
	Gross weight	N content	Gross weight	N content
Imports:				
Industrial chemicals: Ammonium nitrate	58	20	160	56
Fertilizer materials:				
Ammonium nitrate	207,562	63,832	200,015	66,005
Ammonium nitrate-limestone mixtures			37,861	7,951
Ammonium phosphates	129,710	19,457	96,146	14,422
Ammonium sulfate	234,507	49,246	207,964	43,672
Calcium cyanamide or lime nitrogen	28,896	7,224	23,999	6,000
Calcium nitrate	41,675	6,460	54,740	8,485
Nitrogen solutions	77,920	27,272	82,163	28,757
Anhydrous ammonia	[1] 17,453	[1] 14,346	158,264	130,093
Potassium nitrate or saltpeter, crude	4,446	534	3,163	380
Potassium nitrate, sodium nitrate mixtures	38,080	5,712	13,498	2,025
Sodium nitrate	[r] 413,946	[r] 66,231	363,216	58,115
Urea	287,212	130,681	271,485	123,526
Other	50,849	10,170	23,957	4,791
Total	[r] 1,532,314	[r] 401,185	1,536,631	494,278
Exports:				
Industrial chemicals:				
Ammonium nitrate	1,663	582	1,160	406
Anhydrous ammonia and chemical-grade aqua (ammonium content)	3,479	2,860	46,176	37,957
Fertilizer materials:				
Ammonium nitrate	23,309	7,812	87,077	29,171
Ammonium phosphates and other nitrogenous phosphatic-type fertilizer materials	185,282	27,792	363,116	54,467
Ammonium sulfate	490,349	102,973	483,784	101,595
Anhydrous ammonia and aqua (ammonia content)	71,802	59,021	102,303	84,093
Nitrogenous chemical materials, not elsewhere classified	13,302	2,660	60,427	12,085
Sodium nitrate	2,384	381	950	152
Urea	32,725	14,726	37,432	16,844
Total	824,295	218,807	1,182,425	336,770

[r] Revised.

[1] Separately classified Sept. 1, 1963; formerly part of other fertilizer materials.

Source: Bureau of the Census.

WORLD REVIEW

NORTH AMERICA

Canada.—Heavy expansion of Canadian anhydrous ammonia production capacity was underway or planned. Total capacity in 1964 was estimated to be about 700,000 tons per year. By the end of 1965, if all planned anhydrous ammonia plants were to be completed, about 1-million tons per year of capacity would be added.

Brockville Chemicals, Ltd., announced plans for expanding production facilities at its Maitland, Ontario, plant. Anhydrous ammonia output was to be increased from about 70,000 tons per year to 150,000 tons per year, nitric acid production capacity doubled, and ammonium nitrate production substantially increased. Also a new 35,000-tons-per-year urea plant was included in the project.

Canadian Industries, Ltd., was reported planning the construction of a 1,000-ton-per-day ammonia plant, but the site was not announced.

Cyanamid of Canada, Ltd., planned construction of a new facility at its Welland plant in Niagara Falls, Ontario. The new plant would produce about 700 tons per day of ammonia and 300 tons per day of urea.

Dow Chemical of Canada, Ltd., planned to add a new ammonia plant at its Sarnia, Ontario, site. The new 400-ton-per-day plant was scheduled for completion in 1965.

A contract was awarded by New Brunswick Development Corp., of Fredericton, New Brunswick, to have a nitrogenous fertilizer facility constructed at Dorchester Cape, New Brunswick. The facility was to

TABLE 6.—World production and consumption of nitrogen compounds, years ended June 30, by principal countries

(Thousand short tons of contained nitrogen)

Country	Production [e]			Consumption [e]		
	1961-62	1962-63	1963-64	1961-62	1962-63	1963-64
Australia	24	22	21	44	55	65
Austria	200	213	219	67	80	86
Belgium	302	332	351	129	143	155
Brazil	13	24	28	72	83	94
British West Indies	29	29	77	25	27	33
Bulgaria	100	107	114	94	80	108
Canada	434	519	540	138	154	165
Ceylon	-----	-----	-----	37	33	35
Chile	192	187	193	25	29	29
China	408	441	496	694	838	937
Cuba	17	28	33	77	77	77
Czechoslovakia	166	177	179	163	171	182
Denmark	-----	-----	11	152	162	170
Finland	61	50	51	69	73	90
France	934	972	1,209	834	898	1,044
Germany:						
East	407	418	421	325	327	356
West	1,504	1,617	1,739	960	1,146	1,131
Greece	-----	-----	6	91	99	109
Hungary	84	88	98	109	150	148
India	177	225	276	416	507	530
Indonesia	-----	-----	17	116	121	132
Ireland	-----	-----	-----	33	39	44
Israel	24	29	29	22	31	31
Italy	864	924	994	482	515	521
Japan	1,365	1,423	1,455	861	903	915
Korea:						
North	94	99	99	105	110	110
South	39	44	63	198	204	222
Malawi, Southern Rhodesia, Zambia	-----	-----	-----	39	42	45
Mexico	44	72	110	171	193	213
Netherlands	496	529	547	290	348	347
Norway	344	363	388	61	67	71
Pakistan	26	82	96	88	99	121
Peru	13	20	20	28	39	47
Philippines	8	9	9	61	53	64
Poland	323	352	377	342	357	395
Portugal	73	101	126	84	80	88
South Africa, Republic of	99	131	132	105	121	127
Spain	161	179	205	369	392	413
Sweden	66	61	69	134	143	157
Switzerland	28	28	28	29	31	32
Taiwan	77	94	111	126	126	143
U.S.S.R	1,289	1,560	1,932	1,156	1,400	1,731
United Arab Republic (Egypt)	117	123	132	212	247	270
United Kingdom	745	820	895	780	850	945
United States	4,364	4,977	5,699	4,560	5,138	5,952
Yugoslavia	14	39	77	91	164	214
Total [1]	15,792	17,609	19,881	15,657	17,635	19,760

[e] Estimate.

[1] Includes quantities for minor producing and consuming countries not listed above.

Source: Nitrogen. No. 33, January 1965, pp. 16-17.

consist of a 150-ton-per-day nitric acid plant, a 190-ton-per-day ammonium nitrate plant, and a nitrogen solution plant—all scheduled for completion in 1965.

Sherrit Gordon Mines, Ltd., had an ammonium phosphate plant under construction at Fort Saskatchewan, Alberta, for producing 125,000 tons per year of product. The firm also started a program to expand its anhydrous ammonia and urea facilities, increasing capacities of each by about 200 tons per day.

In addition, Northwest Nitro Chemicals, Ltd., planned doubling ammonia capacity to 88,000 tons per year, Consolidated Mining & Smelting Co. was increasing ammonia production capacity to 150,000 tons per year, and Western Cooperative Fertilizers, Ltd., was constructing a new 70,000-ton-per-year ammonia plant at Calgary, Alberta.

Mexico.—Petroleos Mexicanos began production at a new 200-ton-per-day urea plant at Salamanca.

Trinidad.—A new 200,000-ton-per-year anhydrous ammonia plant at Point Lisas went into production bringing the total ammonia capacity at this site to 235,000 tons per year. Federation Chemicals, Ltd., a subsidiary of W. R. Grace & Co., owns and operates the facility. W. R. Grace & Co. had two sea-going tankers built for transporting the anhydrous ammonia at atmospheric pressure and minus 28° F to overseas markets. Each tanker has a liquid ammonia capacity of 9,000 tons and about 300 tons of solid nitrogenous fertilizers such as urea or ammonium sulfate. Federation Chemicals, Ltd. planned to start construction on a second 200,000-ton-per-year plant before the end of 1964 and scheduled completion for late in 1965.

SOUTH AMERICA

Brazil.—Petrobras, a State owned petroleum company, was planning the erection of a 70,000-ton-per-year plant at San Salvador. An ammonia plant was under construction at the same location.

Colombia.—A 700-ton-per-day anhydrous ammonia plant was planned for Barranquilla to be completed by late 1965. Petroquimica del Atlantico, S.A., a new company to operate the plant, was to be formed by a U.S. firm, International Development & Investment Co., and two Colombian firms, Cervecerias Barranquilla y Bolivar, S.A., and Bavaria, S.A.; the U.S. firm was to furnish 50 percent of the capital.

Peru.—An agreement was reportedly reached between a group of Japanese chemical engineering firms and the Peruvian Fertilizer Corp. whereby the Japanese firms would construct for the Peruvian corporation a nitrogen fertilizer complex consisting of a 150-ton-per-day ammonia plant, a 260-ton-per-day urea plant, and an ammonium nitrate plant of 200-ton-per-day capacity. The site selected for the complex was not announced.[2] A group of West German companies were reported to be constructing, at Cuzcos, a calcium ammonium nitrate fertilizer plant with a daily capacity of 190 tons. The plant was being built for the State and was expected to be on stream early in 1965.

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[2] Chemical Age (London). Japanese Firms to Build Fertilizer Complex in Peru. V. 92, No. 2358, Sept. 19, 1964, p. 412.

TABLE 7.—Chile: Exports of nitrate in 1964, by countries[1]

(Thousand short tons)

Destination	Quantity	Destination	Quantity
Argentina	12,412	Middle East	3,267
Belgium	26,825	Netherlands	51,157
Brazil	38,150	Peru	10,097
China	13,285	Portugal	3,307
Colombia	1,003	Spain	155,224
Denmark	32,739	Sweden	5,181
France	57,375	United Kingdom	11,633
Germany	3,563	United States	412,123
Greece	4,359	Uruguay	1,224
India	12,225	Yugoslavia	31,146
Japan	13,448	Other countries [2]	12,456
Lebanon	1,716	In transit	47,676
Libya	1,689		
Mexico	17,102	Total	980,382

[1] Includes 83,649 tons of potassium nitrate.
[2] Includes Bolivia, Ecuador, El Salvador, Guatemala, Jordan, Nicaragua, Panama, Syria; each received less than 1,000 tons.

EUROPE

Austria.—A new ammonia plant, believed to have a capacity of about 100,000 tons per year, was to be constructed for Osterreichiche Stickstoffwerke A.G. at Ling.

Belgium.—Badische Anilin and Soda-Fabrik A.G. of West Germany started erecting a plant near Antwerp to produce, annually, 600,000 tons of nitrophoska, 60,000 tons of caprolactam, and about 250,000 tons of byproduct ammonium sulfate.

Société Belge de l'Azote et des Produits Chimiques du Marly, a Belgium firm, was building a large nitric acid plant at its Marly facility. The plant, capacity unannounced, was due on stream early in 1965.

It was reported that Air Products and Chemicals, Inc. (United States), and Société Génerale de Belgique (Belgium) agreed to form a jointly held Belgium company, Air Products S.A.-N.V. A plant to produce 200,000 tons per year of oxygen, nitrogen, and argon was planned for the new company's first major project.

Bulgaria.—Plans were announced for a new urea plant, with an annual production capacity of 600,000 tons, to be built in the Vratsa district. Also, a contract was reported signed with the Soviet Union for the construction of a 200,000-ton-per-year ammonia plant.

Czechoslovakia.—A contract was made with Power Gas Corp., Ltd. (British) to design and erect a 300-ton-per-day ammonia plant at Sala.[3]

France.—Société de Produits Chimiques d'Auby had a contract with Girdler Corp. (United States) for a shop-fabricated ammonia plant to be shipped and erected in LaPallice where it would become a part of a large fertilizer complex under construction.[4] Société Génerale d'Engrias et Produits Chimiques Pierrefitte planned to expand its ammonia capacity at Soulom by the end of 1965 to 600 tons per day. Houillères du Nord et du Pas-de-Calais was to build a new ammonia plant at its Mazingarbe Works. The new plant was to have an annual capacity of 175,000 tons.

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[3] European Chemical News (London). Czechs Choose ICI Process for Ammonia Plant. V. 5, No. 125, June 5, 1964, p. 16.

[4] Commercia Fertilizer. Girdler Ships Complete NH_3 Plant to France Direct from Louisville, Kentucky. V. 109, No. 3, September 1964, pp. 58, 59.

Germany, West.—Two 350-ton-per-day ammonia plants were reported under construction in the Ruhr District for Scholven-Chemie A.G.

Greece.—A new nitrogenous fertilizer plant at Ptolemais began operating at 50 percent capacity. The daily output of the plant when operating at full capacity was estimated at 300 tons of ammonia, 475 tons of ammonia sulfate, and 385 tons of cal-nitro.

Construction was started at Solonika (northern Greece) on a $110-million chemical complex which included a 105,000-ton-per-year ammonia plant, an oil refinery, and a steel mill.

Hungary.—The country's largest artificial fertilizer plant was to be test operated beginning in October. The plant, part of an integrated chemical complex being constructed at Tiszapalkonya, when in full operation was to have an annual capacity of 350,000 tons of fertilizer. The ammonia unit, the main plant of the group, was designed for an annual output of 100,000 tons.[5] Chemokomplex, the Hungarian chemical authority, awarded a contract to a Belgian engineering group for a 100,000-ton-per-year urea plant to be built at Pétfürdő. The ammonia feed for the plant was to be supplied from a 160,000-tons-per-year ammonia plant under construction in the same area.

Netherlands.—Dutch State Mines (DSM) had a new ammonium sulfate plant of 600 tons daily capacity under construction at Geleen. An ammonia plant having an annual capacity of 220,000 tons also was under construction by DSM with an expansion to 500,000 tons per year scheduled for a later date. A 300,000 ton ammonia plant was under construction at Pernis in Rotterdam harbor by Verenigde Kunstmestfabrieken Mekog-Albatros N.V. and Badische Anilin and Soda-Fabrik A.G. (BASF), each having a one-half interest.

Norway.—A new c oking and ammonia plant was built at Mo-i-Rana in North Norway. The annual ammonia output capacity was estimated at 60,000 tons.

Poland.—Ammonia, nitric acid, and ammonium nitrate facilities were planned for Pulawy. The ammonia facility was to be composed of three 500-ton-per-day plants. A new urea plant at Kedzierzyn with a daily capacity of 500 tons was completed.

Portugal.—The Lavradio Fertilizer Factory on the river Tagus near Lisbon was completed and put into operation for Uniao Fabril do Azoto. The plant was stated to have daily capacities of 180 tons of ammonia and 120 tons of urea. Nitric acid, ammonium nitrate, nitrolimestone, and sulphonitrate production units also were included.

Rumania.—The ammonia, nitric acid and ammonium nitrate units of the Craiova chemical combine were to be completed in 1964. The combine included a 300,000-ton-per-year ammonium nitrate plant and a 100,000 ton annual capacity urea plant.

Spain.—A nitrogenous fertilizer plant with a production capacity of 310,000 tons annually was completed near Málaga. Amoniaco Espanol S.A. was formed by the investors (Esso Mediterranean, Inc., 75 percent, and private Spanish investors, 25 percent) to operate the plant and market the product.

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[5] Chemical Trade Journal and Chemical Engineer (London). Hungary's Largest Chemical Plant Ready For Test. V. 155, No. 4028, Aug. 21, 1964, pp. 239, 247.

Nitrogas, a new company formed by Cros S.A., Energia e Industrias Aragonesas and Catalana de Gas y Electricidad S.A. scheduled an ammonia plant to be constructed at San Adrian. The annual capacity of the new plant was stated to be 100,000 tons.

A 50,000-ton-per-year nitric acid plant was reported to have been supplied to Soc Iberica del Nitrogeno by Montecatini, Soc. Generale per l'Industria Mineraria e Chimica of Italy.

It was announced in December that Spain had banned new investments in ammonia and other nitrogen fertilizer plants. The decree was limited to 3 years.[6]

Sweden.—The synthetic ammonia plant of Svenska Saltpeterverken A.B., Köpin, Sweden, went on stream. The plant's daily production capacity was designed to be 150 tons. It was announced that Société Francaise des Techniques Lummus of France was awarded a contract to construct a nitric acid plant for Stockholms Superfosfat Fabriks A.B. at Landskrona.

U.S.S.R.—An order was placed with Toya Engineering Corp. (Japan) by the Soviet Union for two 180,000-ton-per-year urea plants. Three complete ammonia plants were ordered from Czechoslovakia, two of the plants would have an annual capacity of 220,000 tons and the third would have a 100,000-ton capacity.

United Kingdom.—At least 10 new nitric acid plants were either under construction or under contract for construction in 1964. Fisons Fertilizers Ltd. had two plants at Immingham, one with a 500-ton-per-day capacity using the Chemico process and the other, a 350-ton-per day plant using the Fauser-Montecatini process. Imperial Chemical Industries Ltd. (ICI) had two 520-ton-per-day plants under construction by different engineering firms at Severnside, both to use the Stamicarbon process. One was due on stream in 1965 and the other in 1966. Explosives and Chemical Products Ltd. awarded a contract for constructing a nitric acid plant at Rainham, Essex. The Grande Paroisse medium-high pressure process was to be used. Dyestuffs Division, Imperial Chemical Ltd. had four Kuhlmann process nitric acid plants under construction—three at Wilton with capacities of about 350 tons per day each and one at Huddersfield. One at Wilton and the one at Huddersfield were due on stream in 1964.

Heavy increases in the production capacity of anhydrous ammonia were underway. A contract was awarded late in the fall for a third 300,000-ton-per-year plant for ICI at Billingham. The other two plants, all using the ICI pressure steam reforming process, were already under construction at the same site. Another plant was being built for ICI at Immingham, having a 190,000-ton-per-year capacity.

What was reported to be the largest urea plant in the world was under construction for ICI at Billingham. The new plant, due on stream in 1966, was designed to use the new Toyo Koatsu total recyle process and have a capacity of 1,000 tons per day. Also ICI had under construction, for production in 1965, its first ammonium nitrate plant in England. The plant was designed for 300,000-ton-per-year output.

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[6] Chemical Week. V. 95, No. 26, Dec. 26, 1964, p. 63.

Richardsons Fertilisers Ltd. signed a contract for the first nitric acid plant to be built in Northern Ireland. The plant was one of the several to be built in connection with a substantial expansion program at the firm's Harbour Factory in Belfast.

ASIA

China.—It was announced that a nitrogenous fertilizer plant at Canton began full-scale production. This was one of three such plants reported to have been designed and equipped in China. The second of these plants, at Wuching Chemical Works, Shanghai, with an annual capacity of 100,000 tons was being expanded to include a 40,000-ton-per-year urea plant. A fourth 100,000-ton fertilizer plant was in the designing stage in Shanghai. A new chemical plant at Kaifeng in Honan province was to have started production of ammonia by the Haber-Bosch process.[7] Humphreys and Glasgow Ltd., a British firm, was reportedly under contract to build an ammonia synthesis plant using the ICI steam reforming process, site unannounced.

India.—A large fertilizer project involving five new plants and an annual capacity totaling about 1 million tons was being discussed by the Government of India with a consortium of American companies.

The Nyveli fertilizer project in Madras State was completed late in the year. The project was designed to use lignite for the hydrogen source and to obtain nitrogen from an air separation plant for the production of ammonia. The ammonia is consumed in the production of urea using the Montecatini process. The annual capacity of the urea plant was rated at 150,000 tons.

A plant to produce ammonia, urea, and ammonium sulfate was to be built for the Gujarat State Fertiliser Co., Ltd. at Baroda. Coromandel Fertilizer Ltd. was licensed to erect a fertilizer plant at Vishakapatnam. The company was established jointly by E. I. D. Parry Ltd. of Madras, International Minerals & Chemical Corp. (United States) and California Chemicals Corp. (United States). The plant was licensed to produce 365,000 tons of ammonium phosphate and about 16,000 tons of urea annually. Two additional nitrogenous fertilizer plants were planned by Fertilizer Corp. of India: One to be in Mirzapur district and the other in Durgapur, West Bengal.

Japan.—At least 10 companies were reported to have plans for expanding which would increase total ammonia capacity by over 5,000 short tons daily. Some firms indicated, however, that some old facilities would be closed down after new units were in production.[8]

Korea, South.—The urea plant at Naju was officially turned over to Honan Fertilizer Co., Ltd. (government owned) on April 1, by the builders, a West German consortium headed by Lurgi Gesellschaft für Warmetechnik.[9] This plant was the second chemical fertilizer plant to be built in Korea.

Kuwait.—Kuwait Chemical Fertilizer Co. awarded contracts for the construction of a 600-ton-per-day single-stream urea plant, a 450-ton-per-day sulfuric acid plant, and a 550-ton-per-day ammonium sulfate plant. A contract for a 450-ton-per-day ammonia plant previously had been awarded. Shuaibah was the site chosen for the complex.

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[7] Nitrogen. Nitrogen Fertilizers in China. No. 31, September 1964, pp. 14–17.

[8] Nitrogen. New Ammonia Projects Submitted to JASIA in Japan. No. 33, January 1965, p. 15.

[9] Bureau of Mines. Mineral Trade Notes. V. 59, No. 1, July 1964, pp. 30, 31.

Malaysia.—Parsons Powergas Ltd., a London based engineering firm representing the Ralph M. Parsons Co. of Los Angeles, Calif., and the Power-Gas Corp., Ltd. of Stockton-on-Tees, was awarded the contract to build Malaysia's first ammonia plant. The plant was to be built adjacent to and in connection with Esso's refinery at Port Dickson. Annual production capacity was expected to be nearly 55,000 tons of ammonia.

Contracts were awarded for the construction of a nitric acid plant at Selangor for Chemical Company of Malaysia Ltd., a subsidiary of ICI.

Pakistan.—The Multan gas fertilizer plant of West Pakistan Industrial Development Corp. was formally opened in March. The plant was designed to produce 110,000 tons of ammonia nitrate and 67,000 tons of urea annually.

An agreement was reached between the Government of Pakistan and Esso Standard Eastern, Inc., for the construction of a fertilizer plant to produce ammonia and urea using natural gas from the Mari field.

Taiwan.—An ammonia-urea plant built at Miaoli for Mobile China Allied Chemical Industries Ltd. went on stream. The designed capacities for the plant were 120,000 tons of ammonia and 110,000 tons of urea per year.

The Taiwan Fertilizer Corp. requested permission from the government to erect an ammonia-urea plant in the vicinity of Hsenchu. The expected production capacity was stated to be about 550 tons of urea per day and 450 tons of ammonia per day.

Thailand.—The first fertilizer plant in Thailand was under construction near the Mae Moh lignite mines. The output, when in full production, was expected to be about 30,000 tons of urea and 60,000 tons of ammonium sulfate annually.

AFRICA

South Africa, Republic of.—Fisons (Pty.) Ltd. planned a $24-million nitrogenous plant for Milnerton, 7 miles from Cape Town. The plant was reportedly designed to produce annually a minimum of 80,000 tons of nitrogen as anhydrous ammonia.

Tunisia.—A contract was signed between Indistries Chimiques Maghrebines and Cia. Tecnica Indistria Petroli SpA. (CTIP) whereby CTIP would design, construct, and start up a nitrogenous fertilizer complex at Gabès. The $30-million complex included a 65,000-ton-per-year anhydrous ammonia plant and facilities to produce 200,000 tons of ammonium phosphate and 80,000 tons of ammonium nitrate annually.

United Arab Republic (Egypt).—Two West German companies were awarded a contract to supply and install equipment to expand the El Nasr Fertilizer & Chemical Industries Co. plant at Suez. The expansion project was expected to increase the production of calcium nitrate and ammonium sulfate by over 200 percent providing a total output of over 950,000 tons annually.

Continental Engineering Co., a subsidiary of V.M.F. Stork-Werkspoor, Amsterdam, was awarded a contract to build a 170,000-ton-per-year nitric acid plant at Helwan. The Stamicarbon process was to be used, and acid of 54 percent concentration would be produced.

OCEANIA

Australia.—Ammonia Co. of Queensland Pty. Ltd. was formed jointly by Imperial Chemical Industries of Australia and New Zealand Ltd. (ICIANZ), Australian Chemical Fertilizers Ltd. (ACF), and Shirleys Fertilizer Ltd. The new company was to be the owner of the first synthetic ammonia plant in Queensland. The contract was awarded for the construction at Brisbane of this 150-ton-per-day plant, which was to be in operation in 1966.

The fertilizer and chemical complex of ICIANZ at Botany, New South Wales, was officially opened. The complex included a 100-ton-per-day urea plant using the Stamicarbon process. Units for the production of ammonia, nitric acid, and ammonium nitrate also were included.

An ammonia plant and a nitrogenous fertilizer complex were planned for Kwinana 20 miles south of Perth by the British Petroleum Co. of Australia Ltd., the major partner. The other partners were Cuming-Smith and Mount Lyell Farmers Fertilizers Ltd. Construction was planned for beginning in 1965, and the plant was to have a designed ammonia capacity of 50,000 tons per year.

TECHNOLOGY

The feasibility of fixing and recovering nitrogen compounds as a byproduct of magnetohydrodynamic (MHD) power generators was confirmed on a laboratory scale at the Westinghouse Research Laboratories.[10] In MHD systems, air used in burning the fuel provides the source for nitrogen. At the high operating temperatures, commonly above 5,000° F, the nitrogen from the air readily combines with excess oxygen to form nitric oxide from which nitric acid is made.

Increased operating efficiencies were attained at the new Columbia Nitrogen Corp., nitrogen fertilizer plant at Augusta, Ga., by combining the best of American and European technology. A published report on the design of the facility gave the thermal efficiency of the ammonia plant at 85 percent and the operating efficiency of the nitric acid plant at about 95 percent.[11]

Processes, plant designs, and equipment for anhydrous ammonia production were improved in efforts to reduce plant investments and production costs. The 200-ton-a-day anhydrous ammonia plant of W. R. Grace & Co. at Big Spring, Tex., which started production late in 1963, was designed to use the Casale process. Steam reforming of natural gas conducted at about 300 pounds per square inch gage (psig) was stated to result in substantial savings in compression costs. A report on the process was published.[12]

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[10] Chemical Week. Double Payoff from MHD. V. 94, No. 18, May 2, 1964, pp. 54–56.

[11] Chemical & Engineering News. Nitrogen Complex Combines Technologies. V. 42, No. 16, Apr. 20, 1964, pp. 68–69.

The trend for reducing plant costs was toward the use of higher gas reforming pressures. M. W. Kellogg Co. began designing plants with synthesis gas pressures in excess of 400 psig using an acquired French patent (1,314,577).[13]

A new process for making anhydrous ammonia was developed and patented which employs a steam to hydrocarbon ratio of 6 in the reforming steps.[14] Overall economics in ammonia production, including a reduction in natural gas requirements, was claimed for the process.

While the trend seemed to be toward the construction of larger capacity anhydrous ammonia plants in 1964, one engineering company, Girdler Corp., was selling package ammonia plants of 60-ton-per-day capacity. The 60-ton-per-day unit is constructed in the shop and consists of 22 sections which may be mounted on skids for shipment. The company claimed that within 6 to 8 weeks the plant can be erected and on stream.[15]

The nitric acid plant of Mississippi Chemical Corp. at Yazoo City, Miss., which began production in March 1963, was noted for its high ammonia conversion efficiency. In contrast to normal plant conversion of about 90 to 92.5 percent of the ammonia nitrogen to acid nitrogen, the Yazoo City plant consistantly has operated at 95 percent conversion or better. A report of the design features and operation of the plant was published.[16]

The biochemical conversion of nitrogen to ammonia was studied by biochemists at E. I. du Pont de Nemours & Co., Inc. The chemists found that pyruvate (from salts of pyruvic acid) acts both as a generator of adenosine triphosphate (ATP) and as a reducing agent which are vital in the conversion.[17] Research such as this leads to a complete understanding of the enzymic process of nitrogen-fixation and perhaps to an easier and cheaper synthetic process.

Molecular sieves were used successfully in some high-purity nitrogen plants to remove carbon dioxide (CO_2) and water.[18] Molecular sieves, metal alumina-silicates that absorb preferentially polar and unsaturated compounds, replaced caustic scrubbers for CO_2 removal and dessicant beds for the removal of water.

A new metallized blasting agent, ammonium nitrate containing 5 to 30 percent aluminum chips, was put on the market by The Dow Chemical Co.[19] The agent also contains an organic solvent and water which produces a slurry with about the viscosity of dough. The company claimed the metallized explosive releases 2 to 5 times the energy of conventional industrial explosives and is not sensitive to accidental detonation.

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[12] Chemical Trade Journal and Chemical Engineer. Grace Ammonia Plant Uses Novel Natural Gas Reforming Process. V. 154, No. 3998, Jan. 24, 1964, p. 110.

[13] Chemical Week. Pressure Buildup Brings Down Ammonia Costs. V. 94, No. 13, Mar. 28, 1964, pp. 60–62.

[14] Chemical Engineering. New Ammonia Route Turns the Tables by Championing High Steam Ratios. V. 71, No. 5, Mar. 2, 1964, pp. 32, 34.

[15] Farm Chemicals. The Ammopac on Stream in Less than 8 Weeks. V. 127, No. 9, September 1964, pp. 52–54.

[16] Chemical Engineering. Nitric Acid: Smart Engineering Boosts the Yield. V. 71, No. 7, Mar. 30, 1964, pp. 38–40.

[17] Chemical and Engineering News. Biochemists See New Nitrogen Fixation Path. V. 42, No. 14, Apr. 6, 1964, pp. 23, 24.

[18] European Chemical News (London). Molecular Sieves in High Purity Nitrogen Plant. V. 5, No. 122, May 15, 1964, p. 34.

[19] Mining Engineering. Metallized Explosives to be Marketed by Dow. V. 16, No. 6, June 1964, p. 31.

New uses for nitrogen and nitrogen compounds continued to be developed. Liquid nitrogen was used extensively at South Africa's National Nuclear Research Center at Pelindaba as a refrigerant for controlled freezing at very low temperatures.[20] Gaseous ammonia was used successfully as a fuel in an internal combustion engine for 35 hours in tests at Fort Belvoir, Va., by Army research workers.[21] Techniques and machinery were developed for applying anhydrous ammonia as a cotton defoliant at a reasonable cost. The idea for using anhydrous ammonia for this purpose is not new, and several firms have been working on its possibilities for several years.[22]

The University of Florida conducted experiments to observe the movement of fertilizer nitrogen after it enters the soil. The nitrogen isotope N^{15}, quite rare and valued at $21,000 an ounce, was used in the study.[23] At the Aerojet-General rocket test center in Florida, ammonium perchlorate was being mixed with other ingredients to produce the fuel for the Defense Department's program for big solid-fuel rocket motors.[24] Liquid ammonium phosphate proved to be very effective in combating grass fires in a demonstration conducted by Oklahoma State University. One part ammonium phosphate was mixed with 4 parts of water, and aircraft carrying loads of 125 to 160 gallons applied the mixture on the fire area.[25]

A decision was made to equip all the Foster Wheeler boilers at the Bankside Generating Station, England, with an ammonia injection system to retard corrosion in the air-heaters. Results from detailed investigation and trials showed that the estimated air-heater life using ammonia injection was 12 to 16 years, whereas with tertiary amine injections the interval between retubing was 3 to 4 years.[26]

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[20] South African Mining and Engineering Journal (Johannesburg). Liquid Nitrogen in S.A. Atomic Research. V. 75, pt. 2, No. 3736, Sept. 11, 1964, p. 775.

[21] Chemical & Engineering News. Ammonia Substitutes as Fuel in Internal Combustion Engine. V. 42, No. 39, Sept. 28, 1964, p. 54.

[22] Chemical & Engineering News. Anhydrous Ammonia May Find Use as Cotton Defoliant. V. 42, No. 5, Feb. 3, 1964, p. 53.

[23] Farm Chemicals. $21,000 an Ounce. V. 127, No. 5, May 1964, p. 6.

[24] Chemical & Engineering News. Solid-Propellant Technology: New Dimensions. V. 42, No. 39, Sept. 28, 1964, pp. 50–53.

[25] Stevens, Lee. Liquid Fertilizer for Fire Fighting. Farm Chemicals, v. 127, No. 4, April 1964, pp. 17–18.

[26] Chemical Trade Journal and Chemical Engineer (London). Air-Heater Corrosion Prevention—Bankside Station to use Ammonia Injection. V. 154, No. 4016, May 29, 1964, p. 777.

Perlite

By Timothy C. May [1]

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THE TOTAL QUANTITY of crude perlite sold and used reached a new high in 1964. Production of crude perlite in the United States in 1964 was 6 percent more than in 1963. Output of expanded perlite increased 18 percent over that of 1963.

DOMESTIC PRODUCTION

Crude perlite was produced by 16 companies from 17 mines, compared with 17 companies and 18 mines in 1963. New Mexico continued to lead in producing crude perlite; 340,156 short tons was mined, 80 percent of the U.S. total. Other producing States, in order of output, were California, Arizona, Nevada, Texas, Utah, Colorado, Idaho, and Oregon.

Perlite was expanded in 32 States by 86 companies at 100 plants in 1964, compared with 30 States, 77 companies, and 90 plants in 1963. The increase in numbers is principally due to greater coverage. The largest number of companies was in California, 13; followed by Illinois, 8; Texas, 7; Pennsylvania, 5; New Jersey and New York, 4 each; Colorado, Florida, Indiana, Iowa, Maryland, and Ohio, 3 each. Other States accounted for the remaining portion of expansion companies.

TABLE 1.—Crude and expanded perlite produced and sold or used by producers in the United States

(Thousand short tons and thousand dollars)

Year	Crude perlite						Expanded perlite		
	Quantity mined	Sold		Used at own plant to make expanded material		Total quantity sold and used	Quantity produced	Sold	
		Quantity	Value	Quantity	Value			Quantity	Value
1955–59 (average)	384	203	$1,784	99	$735	303	255	253	$12,956
1960	385	214	1,847	98	818	312	248	244	13,046
1961	374	196	1,665	114	998	310	240	235	12,605
1962	408	198	1,611	122	1,052	320	238	234	12,536
1963	404	203	1,631	122	1,096	325	272	270	14,497
1964	427	211	1,845	139	1,228	350	320	319	14,533

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[1] Commodity specialist, Division of Minerals.

TABLE 2.—Expanded perlite produced and sold by producers in the United States

(Thousand short tons and thousand dollars)

State	1963				1964			
	Quantity produced	Sold			Quantity produced	Sold		
		Quantity	Value	Average value per ton		Quantity	Value	Average value per ton
California	27	27	$1,654	$60.16	20	20	$1,266	$62.06
Florida	7	7	475	69.28	7	7	405	61.49
Illinois	(1)	(1)	(1)	(1)	52	52	1,930	36.88
Iowa	(2)	(2)	(2)	(2)	6	6	232	40.71
Kansas	(3)	(3)	26	101.98	1	1	33	57.42
Michigan	2	2	126	56.44	(1)	(1)	(1)	(1)
New Jersey	8	8	508	64.26	(1)	(1)	(1)	(1)
New York	10	10	524	51.78	(1)	(1)	(1)	(1)
Ohio	(1)	(1)	(1)	(1)	7	7	498	69.09
Pennsylvania	14	14	847	60.31	14	14	842	61.66
Texas	26	26	1,512	57.73	40	40	2,492	61.80
Other Eastern States [4]	127	127	[r] 6,808	54.01	121	120	5,001	41.41
Other Western States [5]	51	49	2,017	41.26	52	52	1,833	35.38
Total	272	270	14,497	53.69	320	319	14,533	45.50

[r] Revised.

[1] Included with "Other Eastern States."

[2] Included with "Other Western States."

[3] Less than 500 tons.

[4] Includes Georgia (1964), Indiana, Kentucky, Maryland, Massachusetts, Mississippi (1964), New Hampshire, North Carolina, Tennessee, Virginia, and Wisconsin.

[5] Includes Arizona, Colorado, Idaho, Louisiana, Minnesota, Missouri, Nebraska, Nevada, Oregon, and Utah.

CONSUMPTION AND USES

Producers reported the following end-use percentages for expanded perlite: building plaster aggregate, 35; filter aid, 15; concrete aggregate, 13; insulation (loose fill), 2; soil conditioning, 2; filler, 1; and other, 32.

PRICES

The average value of crude perlite crushed, cleaned, and sized, f.o.b. producers' plants, sold to expansion plants was $8.74 per short ton compared with $8.05 in 1963. The average value of crude perlite used by producers in their own expanding plants was $8.83 compared with $8.94 in 1963. A weighted average of these two categories of crude perlite was $9.04 compared with $8.39 in 1963.

The average value of all expanded perlite sold in 1964 was $45.50 compared with $53.69 in 1963.

WORLD REVIEW

The United States in 1964 produced, expanded, and consumed more perlite than any other country.

Canada.—Crude perlite was imported from the United States and expanded by 8 companies at 10 plants. Production of expanded perlite in 1963 was 89,594 cubic yards valued at Can$722,682, a decrease of 6.8 percent in volume and 1.2 percent in value from that of 1962.

Plaster aggregate accounted for 88 percent of 1963 production; 3 percent was used in insulating concrete, and 9 percent was used in insulation, horticulture, acoustics, and other uses. Expanded perlite sold at 25 to 40 cents a cubic foot and was marketed in bags containing 3 and 4 cubic feet.[2]

Germany, West.—There were six furnaces for the expansion of perlite in West Germany according to a representative of Deutsche Perlite Gesellschaft m.b.H., Dormund, Germany, at the annual meeting of the Perlite Institute, Inc. Production in 1964 was 3.5 million cubic feet of expanded perlite or about 900,000 bags. Forty percent of the output was used for plaster; 20 percent for floor insulation; 15 percent for insulation of chimneys and brick walls; 15 percent for high- and low-temperature insulation; 5 percent for horticultural use; and the remainder for other uses.

Ireland.—Production of crude perlite in Northern Ireland in 1964 was 1,977 tons compared with 4,362 tons in 1963.

Japan.—According to a representative of Mitsui Mining & Smelting Co., Ltd., Tokyo, at the annual meeting of Perlite Institute, Inc., production of expanded perlite in 1964 was estimated at 1.8 million bags. The major portion of crude perlite was mined in Fukushima Prefecture in the northern part of the main island. Application of expanded perlite was the following in percentages: building industry, 30; block, board, pipe covering, 40; loosefill, 10; soil conditioner and horticultural use, 10; and filter aids, 10.

TECHNOLOGY

Technical papers presented at the annual meeting of the Perlite Institute, Inc., at New York, N.Y., in April 1964, covered production and maintenance, classification and dust collection, quality control, and materials handling at perlite expansion plants.

Perlite was used as an insulation material in the manufacture of a 100,000-gallon sphere built by Chicago Bridge & Iron Corp. to store liquid hydrogen. The 36.5-foot steel outer shell is separated from the 30.5-foot aluminum alloy inner shell by a layer of perlite.[3]

Processing, separation, and quality control of expanded perlite made in Washington, D.C., from ore shipped from Colorado is described.[4]

The Technical Committee of Perlite Institute, Inc., issued a booklet describing various tests pertaining to perlite. The pamphlet, a first edition, covers 19 tests and selected specifications of the American Society for Testing & Materials applicable to the perlite industry.[5]

The Hungarian Academy of Horticulture and Viticulture experimented with uses for expanded coarse perlite. Good results were obtained when using expanded perlite in the cultivation of new plants. Perlite is produced in various grain sizes at the Palhaza mines, and the perlite dust obtained from the local crushing mill is used in making green glass.[6]

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[2] Wilson, H. S. Lightweight Aggregates, 1963 (Preliminary). Canada Dept. Mines and Tech. Surveys (Ottawa), June 1963, 6 pp.

[3] Iron Age. Meets Cryogenic Need. V. 193, No. 13, March 1964, p. 95.

[4] Taeler, D. H. Perlite Popping in the Nation's Capitol. Minerals Processing, v. 5, No. 7, July 1964, pp. 31–33.

[5] Perlite Institute, Inc. Test Methods and Related Standards. New York, April 1964, 80 pp.

A process was patented for the manufacture of porous acoustical tiles. Expanded perlite particles are bonded together with a thin-fired ceramic coating consisting of a proportioned mixture of bentonite and kaolin.[7]

A patent was granted for the use of perlite as one of the materials in the manufacture of an exothermic composition for application in metallurgy.[8]

A design for a vertical apparatus for expanding perlite was patented. The sized crude material is suspended in a stream of heated air directly under pressure. Suction is exerted at the top of the shaft to draw off the bulky, expanded material.[9]

The use of expanded perlite in the manufacture of a heat-resistant refractory concrete was patented in France.[10]

A Japanese patent was issued for the use of perlite in the manufacture of composite insulating refractories.[11]

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[6] Mining Journal (London). Uses for Perlite. V. 262, No. 6701, January 1964, p. 71.

[7] Lewis, J. H. (assigned to the Celotex Corp.). Acoustical Tiles, Methods and Compositions. U.S. Pat. 3, 132,956, May 12, 1964.

[8] Walsh, J. P., and H. F. Bishop (assigned to Exomet, Inc.). Exothermic Composition Containing Perlite. U.S. Pat. 3,132,061, May 5, 1964.

[9] Clute, F. H. Vacuum Expansion Exfoliater. U.S. Pat. 3,145,019, Aug. 18, 1964.

[10] Berther, R. M. (assigned to Electricite de France). French Pat. 1,344,972, Oct. 28, 1963.

[11] Kitano, S. Japanese Pat. 2243, Mar. 4, 1964.

Phosphate Rock

By Richard W. Lewis [1]

❖

FOR six consecutive years the domestic production marketable phosphate rock has increased. This consistent annual increase was due almost entirely to increased demand for fertilizers. In 1964, marketable production was 16 percent above that of 1963. This is the largest percentage annual increase in marketable production since the start of its upward trend in 1958.

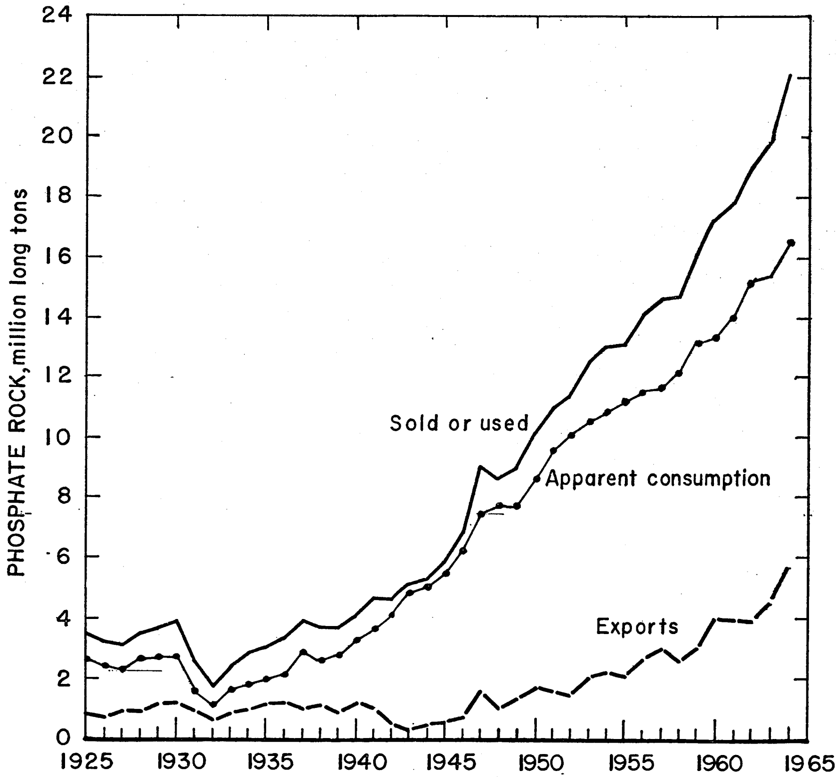

FIGURE 1.—Phosphate rock (sold or used), apparent consumption and exports.

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[1] Commodity specialist, Division of Minerals.

TABLE 1.—Salient phosphate rock statistics

(Thousand long tons and thousand dollars)

	1955–59 (average)	1960	1961	1962	1963	1964
United States:						
Mine production	46, 607	54, 338	60, 535	56, 746	[r] 61, 598	66, 494
Marketable production	14, 547	17, 516	18, 559	19, 382	[r] 19, 855	22, 960
Value	$90, 688	$117, 041	$130, 535	$134, 304	[r] $139, 861	$161, 067
Average per ton	$6. 23	$6. 68	$7. 03	$6. 93	$7. 04	$7. 02
Sold or used by producers	14, 543	17, 202	17, 842	19, 060	19, 860	22, 081
Value	$91, 271	$115, 363	$125, 593	$134, 222	$140, 642	$156, 738
Average per ton	$6. 28	$6. 71	$7. 04	$7. 04	$7. 08	$7. 10
Imports for consumption	117	129	134	134	161	156
Value	$2, 957	$3, 754	$3, 629	$3. 551	$3, 651	$3, 329
Average per ton	$25. 27	$29. 04	$27. 08	$26. 57	$22. 68	$21. 33
Exports [1]	2, 724	3, 994	3, 918	3, 934	[r] 4, 547	5, 691
P_2O_5 content	883	1, 290	1, 261	1, 269	[r] 1, 480	1, 835
Value	$17, 703	$26. 632	$26, 924	$27, 567	[r] $31, 881	$39, 717
Average per ton	$6. 50	$6. 67	$6. 87	$7. 01	[r] $7. 01	$6. 98
Consumption, apparent [2]	11, 936	13. 337	14, 058	15, 260	[r] 15, 474	16, 546
World: Production	33, 750	41, 170	44, 780	47, 320	[r] 50, 590	57, 910

[r] Revised.
[1] As reported to the Bureau of Mines by domestic producers.
[2] Measured by sold or used plus imports minus exports.

LEGISLATION AND GOVERNMENT PROGRAMS

The Bonneville Power Administration (BPA) requested a $1 million appropriation to begin building a power transmission line into southern Idaho where the Administration planned to supply energy at 2.2 mills per kilowatt hour to electric-furnace phosphorus producers. The request, however, was rejected by both the House of Representatives and the Senate.

H.R. 9638, a bill to amend the Mineral Leasing Act of February 25, 1920, as amended, in order to promote the development of phosphate on the public domain was passed and signed into Public Law 88–548 on August 31. The amendment provided for an individual, association, or corporation to take, hold, own, or control up to 20,480 acres at one time by phosphate leases or permits. This was double the area that had been allowed previously.

The Department of the Interior agreed to permit Susquehanna-Western Corp. to prospect for phorsphate rock in a designated area of Federal land southwest of Lander, Wyo.

In December, the Department of Justice filed suit in U.S. District Court in New York to break up the Concentrated Phosphate Export Association (CPEA) for alleged antitrust law violations.

DOMESTIC PRODUCTION

Florida and the Western States accounted for most of the increased domestic marketable rock production, each exceeding its 1963 output by 17 percent. Florida's production of over 17 million tons accounted for nearly 75 percent of the total domestic output, the Western States 15 percent, and Tennessee slightly less than 11 percent.

The American Agricultural Chemical Co. (AAC), a subsidiary of Continental Oil Co., was constructing a $13 million phosphate rock processing plant about 6 miles southeast of Pierce, Fla. The new facility was expected to be in operation early in 1965. In addition, it was reported late in the year that AAC had ordered two new draglines, each having 35-cubic-yard buckets.

Armour Agricultural Chemical Co. had a new phosphoric acid plant under construction at its Bartow, Fla., facilities. The company planned to discontinue production of triple superphosphate at the site after the new acid plant goes on stream.

One of the largest phosphate processing facilities in the United States was underway for Consumers Cooperative Association in Polk County, Fla. The new complex included plants for the manufacture of sulfuric acid, phosphoric acid, granular triple superphosphate, and diammonium phosphate. The project, estimated to cost $20 million, was scheduled for operation late in 1965.

Construction was started on a fertilizer plant near Soda Springs, Idaho, for El Paso Natural Gas Products Co. The facility was designed for an annual output of 90,000 tons of P_2O_5 in a full line of phosphatic fertilizers and was to begin operations early in 1966. Total investment was estimated to be between $10 and $12 million. The firm earlier in the year acquired the phosphate reserves and properties of Central Farmers Fertilizer Co. at Georgetown, Idaho, which included an elemental phosphorus plant and the facilities for producing phosphoric acid and triple superphosphate. The new plant at Soda Springs will produce acid by the "wet process"; however, a study was underway to determine the feasibility of reactivating the Georgetown electric furnace to produce elemental phosphate. The furnace unit was closed down in 1963 by Central Farmers Fertilizer Co.

FMC Corp. announced a $3 million expansion of its operation at Pocatello, Idaho. Most of the expenditure was scheduled to increase furnace capacity for producing elemental phosphorus. The expanded operations were expected to require 10 to 15 additional employees at the Pocatello plant and about the same number at the Gay mine on the Fort Hall Indian Reservation. The Gay mine, operated by J. R. Simplot Co., supplies FMC Corp. with furnace-grade phosphate rock. FMC, however, indicated intentions of becoming a basic producer of phosphate rock when it became the successful bidder for leases on over 1,000 acres of Federal phosphate land near Soda Springs, Idaho. Also the firm was reported to have leased approximately 10,000 acres of North Carolina State owned land in the Beaufort County phosphate area.

Hooker Chemical Corp. discontinued the manufacture of white phosphorus at its plant in Niagara Falls, N.Y. The plant was obsolete and the production costs were excessive. The firm continued producing phosphorus compounds at the Niagara plant using phosphorus from its electric furnaces in Columbia, Tenn. Hooker Chemical Corp. acquired 90 percent of the common stock of National Phosphate Corp. and secured an option on the remaining 10 percent to be taken up by the end of 1969. National Phosphate Corp. was to continue operations as a subsidiary. Later a new 1,000-ton-per-day ammonium phosphate plant was planned for construction in Louisiana, to be operated by National.

International Minerals & Chemical Corp. (IMC) was to close its Prairie phosphate processing plant at Mulberry, Fla., stating that it was economically impossible to meet the Florida State Board of Health requirements for dust control. IMC more than doubled the capacity of its Noralyn plant at Bartow, Fla., to aid in compensating for the loss of the Mulberry output. In February IMC began operating a new granulation unit at its Bonnie plant at Bartow, producing diammonium phosphate and triple superphosphate. Before the end of the year, the firm started a $5 million expansion program to increase the phosphate chemical output of the Bonnie plant by 50 percent. The program called for a second diammonium phosphate plant with an annual capacity of 260,000 tons and a third phosphoric acid unit having an output capacity of 165,000 tons (P_2O_5 content) annually. In order to increase ore production at its Achan mine which was to supply the new processing plants, IMC ordered a new dragline with a bucket reported as having a capacity of nearly 40 cubic yards.

Monsanto Co. planned adding two new electric furnaces at its elemental phosphorus plant at Soda Springs, Idaho. One furnace was to be ready for operation in 1964, while the other would not be completed until late 1965 or early 1966. Upon completion of the project, output of elemental phosphorus was expected to be tripled.

TABLE 2.—Mine production of phosphate-rock ore in the United States, by States

(Thousand long tons)

Year	Rock	P_2O_5 content	Rock	P_2O_5 content	Rock	P_2O_5 content
	Florida		North Carolina		Tennessee [1]	
1955-59 (average)	41, 355	4, 980	--------	--------	2, 793	571
1960	48, 007	6, 753	--------	--------	2, 931	636
1961	54, 403	7, 552	--------	--------	3, 321	734
1962	49, 600	7, 093	--------	--------	3, 812	855
1963	54, 445	[r] 8, 069	--------	--------	4, 131	921
1964	58, 078	9, 410	80	3	4, 217	935

Year	Rock	P_2O_5 content	Rock	P_2O_5 content
	Western States [2]		Total	
1955-59 (average)	2, 459	645	46, 607	6, 196
1960	3, 400	893	54, 338	8, 282
1961	2, 811	740	60, 535	9, 026
1962	3, 334	875	56, 746	8, 823
1963	[r] 3, 022	[r] 808	[r] 61, 598	[r] 9, 798
1964	4, 119	1, 020	66, 494	11, 368

[r] Revised.
[1] Includes brown rock, white rock, and blue rock in 1955-58.
[2] Includes Arkansas (1963 and 1964), Idaho, Montana, Utah, and Wyoming.

Construction of a $10 million mining facility was started for Occidental Petroleum Corp. in Hamilton County, Fla. The phosphate deposit to be mined was estimated to contain 30 million tons of recoverable ore. Occidental Corp. of Florida, a wholly owned subsidiary of Occidental Petroleum Corp., was formed to operate the new mine which was named the Suwannee River mine. Production was expected to begin in the summer of 1965. It was reported that Occidental also took an option on 9,000 acres of phosphate land in central Florida, and that the construction of a superphosphoric acid plant was begun south of Bartow by Occidental Research and Survey Co., another subsidiary of the oil company.

Olin Mathieson Chemical Corp. started on a $40 million program for expanding its fertilizer facilities. A new 500-ton-per-day phosphoric acid plant was planned to replace the existing 350-ton plant at Pasadena, Tex., while an ammonium phosphate plant was being built at Joliet, Ill., and scheduled for operation late in 1964.

Montana Phosphate Products Co. was to complete its $6 million Douglas mine and flotation plant near Philipsburg, Mont. The plant was designed for an annual output of 300,000 tons of concentrates.

San Francisco Chemical Co. began a $1 million expansion program which included a 50 percent increase in production of its Cherokee mine in northwestern Utah and a new calciner at the Leefe, Wyo., beneficiation plant.

J. R. Simplot Co. was reported to be expanding all of its facilities in Pocatello, Idaho, and planning the rebuilding of the washing plant at the Conda mine near Soda Springs, which would double its production.

Smith-Douglass Co. began a multi-million-dollar expansion of its Coronet plant at Plant City, Fla. A $15 to $20 million phosphate defluorination plant was included in the project. Late in December, Borden Chemical Co. acquired the assets and business of Smith-Douglass Co. with a stock transfer of nearly 977,000 shares. Smith-Douglass Co. was to continue to operate as a division of Borden Chemical Co.

North Idaho Phosphate Co. was organized as a joint venture of Stauffer Chemical Co. and Bunker Hill Co. to operate new phosphoric acid and ammonium phosphate facilities at Kellogg, Idaho, with Stauffer responsible for the installation of equipment. Stauffer Chemical Co., 50 percent owner of Western Phosphates Inc., bought the remaining stock from Kennecott Copper Corp. and American Smelting and Refining Co., each having a 25-percent interest. Western Phosphates Inc. produces ammonium phosphate, phosphoric acid, and superphosphates at Garfield, Utah. Stauffer Chemical Co. also acquired a plant for manufacturing phosphate esters from the Celanese Corporation of America, and was attempting to buy out the Mountain Copper Co., Ltd. (London), who with Stauffer was an equal partner in San Francisco Chemical Co. of Montpelier, Idaho.

Susquehanna-Western Corp. was planning a multi-million-dollar project to develop phosphate rock deposits in central Wyoming.

Texas Gulf Sulphur Co. (TGS) was progressing with its $45 million project at its Lee Creek phosphate deposits, on the Pamlico River, near Aurora, N.C. Contracts were awarded for mill design and construction and for two draglines, one having a 19-cubic-yard bucket and the other having a 72-cubic-yard bucket, the largest ever used in phosphate mining. Production of phosphate rock was expected to be at an annual rate of 3 million tons when operating at full capacity. Commercial production was scheduled to begin in 1966. TGS mined about 90,000 tons of ore during the year and tested it in a pilot plant.

Other firms holding leases and active in this phosphate area included Magnet Cove Barium Corp. Ltd., and North Carolina Phosphate Corp. In 1964, FMC Corp. acquired leases in the area and began exploration. The Norfolk Southern Railway Co. announced in November that it would construct 28 miles of railway in Beaufort County, N.C., to serve the phosphate mines.

Tennessee Valley Authority completed its new 25,000-kw rotating phosphorus furnace at Muscle Shoals, Ala., and placed it in operation. The furnace, with an annual capacity of 16,000 to 17,000 tons of elemental phosphorus, replaced several obsolete furnaces.

Virginia-Carolina Chemical Co., which changed its name to V–C Chemical Co., planned construction of a phosphoric acid plant at Cal-Industrial Center, Gary, Ind. V–C Chemical Co. also began operating its new $4 million elemental phosphorus furnace plant at Mt. Pleasant, Tenn. In addition, the firm opened a new mining area at Cedar Branch near Bartow, Fla. It was announced that the life of its Clear Springs processing plant was extended 10 years by the opening of the new mine.

Central Phosphates, Inc., reportedly a subsidiary of Cherokee Chemical Co., announced that it would build a $15 to $20 million fertilizer complex in Hillsborough County, Fla. Cherokee Chemical Co. purchased phosphate land near Bartow, Fla., and planned to operate an open-pit mine on the property. It was reported that Kerr-McGee Oil Industries, Inc., acquired phosphate lands in both Florida and Idaho. Dixie Guano Co. completed new production and shipping facilities at its plant at Laurinburg, S.C., doubling its output capacity of superphosphate. Hydrite Chemical Co. put a new phosphoric acid plant into operation at Milwaukee, Wis.

TABLE 3.—Marketable production of phosphate rock in the United States, by States

(Thousand long tons)

Year	Florida[1]		North Carolina		Tennessee[2]		Western States[3,4]		Total	
	Rock	P_2O_5 content	Rock	P_2O_5 content	Rock	P_2O_5 content	Rock	P_2O_5 content	Rock	P_2O_5 content
1955–59 (average)	10,635	3,517			1,724	450	2,188	595	14,547	4,562
1960	12,321	4,052			1,939	506	3,256	885	17,516	5,443
1961	13,789	4,531			2,235	575	2,535	698	18,559	5,804
1962	13,949	4,543			2,418	638	3,015	823	19,382	6,004
1963	14,592	4,818			2,352	612	[r] 2,911	[r] 791	[r] 19,855	[r] 6,221
1964	17,108	5,656	6	2	2,441	640	3,405	932	22,960	7,230

[r] Revised.

[1] Salable products from washers and concentrates of land pebble and hard rock, and drier production of soft rock (colloidal clay).

[2] Salable products from washers and concentrates of brown rock, brown-rock ore used directly, and blue rock and white rock in 1955–58.

[3] Mine production of ore (rock), plus a quantity of washer and drier production.

[4] Includes Arkansas (1963 and 1964), Idaho, Montana, Utah, and Wyoming.

The U.S. Geological Survey made a report on the discovery of low-to-medium grade phosphate deposits about 80 feet thick in Dry Bread Hollow, Weber County, Utah.[2] The discovery led to several firms filing for phosphate rights with the U.S. Bureau of Land Management. Some of those reported as filing for land were Bear Creek Mining Co., Kern County Land Co., and Phillips Petroleum Co.

Interest in reworking old phosphate waste dumps in Florida was increased. Wellman-Lord Engineering, Inc. and New Concept Mining Co. were already engaged in recovering waste-dump phosphate, while Minerals Recovery Corp. was to have started operations at Sand Mountain, about 1 mile south of Fort Meade, Fla. Edgar Kaolin and Plastic Co. and Minerals Recovery Corp. were reported to have leased several tailing dumps.

CONSUMPTION AND USES

A preliminary report by the U.S. Department of Agriculture showed that fertilizers consumed during the year ending June 30, 1964, contained 3,360,000 tons of available P_2O_5, which was a 9.4 percent increase over the preceding 12-month period.

TABLE 4.—Florida phosphate rock sold or used by producers, by kinds

(Thousand long tons and thousand dollars)

Year	Rock	P_2O_5 content	Value		Rock	P_2O_5 content	Value	
			Total	Average per ton			Total	Average per ton
	Hard rock				Soft rock[1]			
1955-59 (average)	85	30	$716	$8.42	59	12	$418	$7.08
1960	74	26	639	8.64	45	9	372	8.33
1961	73	26	672	9.16	39	8	303	7.87
1962	70	25	659	9.34	33	6	275	8.39
1963	76	27	723	9.48	33	7	269	8.11
1964	77	27	747	9.72	28	5	225	8.18
	Land Pebble				Total			
1955-59 (average)	10,470	3,468	$65,454	$6.25	10,614	3,510	$66,588	$6.27
1960	12,132	3,984	80,905	6.67	12,251	4,019	81,916	6.69
1961	12,667	4,168	88,395	6.98	12,779	4,202	89,370	6.99
1962	13,624	4,460	93,669	6.88	13,727	4,491	94,603	6.89
1963	14,377	4,722	100,749	7.01	14,486	4,756	101,741	7.02
1964	16,252	5,331	115,513	7.11	16,357	5,363	116,485	7.12

[1] Includes material from waste-pond operations.

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[2] Schell, E. M., and W. C. Gere. Preliminary Report on the Phosphate Deposits and Stratigraphy of Permian Rocks in Dry Bread Hollow, Weber County, Utah. U.S. Geological Survey, open-file report, Washington, D.C.

TABLE 5.—Tennessee phosphate rock[1] sold or used by producers

(Thousand long tons and thousand dollars)

Year	Rock	P_2O_5 content	Value	
			Total	Average per ton
1955–59 (average)	1,768	461	$12,731	$7.20
1960	1,927	502	15,319	7.95
1961	2,291	592	19,099	8.34
1962	2,476	654	20,173	8.15
1963	2,395	625	18,303	7.64
1964	2,458	645	19,074	7.76

[1] Includes small quantity of Tenn. blue rock and white rock in 1955–58.

TABLE 6.—Western States phosphate rock sold or used by producers

(Thousand long tons and thousand dollars)

Year	Idaho				Montana[1]			
	Rock	P_2O_5 content	Value		Rock	P_2O_5 content	Value	
			Total	Average per ton			Total	Average per ton
1955–59 (average)	1,354	351	$6,236	$4.61	807	239	$5,715	$7.08
1960	1,973	520	10,269	5.21	1,051	311	7,859	7.47
1961	1,687	434	8,913	5.28	1,085	323	8,211	7.57
1962	1,744	444	10,164	5.83	1,113	338	9,282	8.35
1963	1,739	432	10,015	5.76	1,240	374	10,583	8.53
1964	1,964	506	9,802	4.99	1,302	393	11,390	8.75

[1] Includes Arkansas in 1963 and 1964, Utah in 1955 and 1961–64, and Wyoming in 1955–64.

TABLE 7.—Phosphate rock sold or used by producers in the United States, by grades and States

(Thousand long tons)

Year and grade—B.P.L.[1] content (percent)	Florida		Tennessee		Western States		Total United States	
	Quantity	Percent of total	Quantity	Percent of total	Quantity	Percent of total	Quantity	Percent of total
1963:								
Below 60	57	(2)	2,099	88	1,695	57	3,851	19
60 to 66	1,735	12	296	12	1,284	43	601	3
66 to 68							1,390	7
68 to 70	3,120	22					4,444	22
70 to 72	2,958	20	--------	--------	--------	--------	2,958	15
72 to 75	3,854	27	--------	--------	--------	--------	3,854	20
75 to 77	[3] 2,762	19	--------	--------	--------	--------	2,762	14
Total	14,486	100	2,395	100	2,979	100	19,860	100
1964:								
Below 60	52	(2)	2,060	86	1,780	55	3,892	18
60 to 66	396	3	326	14	84	3	806	4
66 to 68	2,778	17	29	(2)	80	2	2,887	13
68 to 70	4,558	27	29	(2)	1,211	37	5,798	27
70 to 72	1,185	8	14	(2)	111	3	1,310	5
72 to 75	4,378	26	--------	--------	--------	--------	4,378	19
75 to 77	2,906	18	--------	--------	--------	--------	2,906	14
Plus 77	104	1	--------	--------	--------	--------	104	(2)
Total	16,357	100	2,458	100	3,266	100	22,081	100

[1] Bone phosphate of lime, $Ca_3(PO_4)_2$.
[2] Less than 0.5 percent.
[3] Includes some higher grade rock.

TABLE 8.—Phosphate rock sold or used by producers in the United States, by uses and States

(Thousand long tons)

State and use	1955–59 (average)		1960		1961		1962		1963		1964	
	Rock	P_2O_5 content	Rock	P_2O_5 content	Rock	P_2O_5 content	Rock	P_2O_5 content	Rock	P_2O_5 content	Rock	P_2O_5 content
Florida:												
Agriculture	7, 655	2, 546	8, 385	2, 774	9, 006	2, 990	9, 746	3, 210	10, 043	3, 305	10, 586	3, 497
Industrial	590	192	387	116	377	114	592	183	471	151	685	219
Exports	2, 369	772	3, 479	1, 129	3, 396	1, 098	3, 389	1, 098	3, 972	1, 300	5, 086	1, 647
Total	10, 614	3, 510	12, 251	4, 019	12, 779	4, 202	13, 727	4, 491	14, 486	4, 756	16, 357	5, 363
Tennessee:												
Agriculture	332	89	184	56	148	46	103	32	127	39	86	25
Industrial	1, 435	372	1, 743	446	2, 143	546	2, 373	622	2, 268	586	2, 372	620
Total	1, 767	461	1, 927	502	2, 291	592	2, 476	654	2, 395	625	2, 458	645
Western States:												
Agriculture	483	154	823	260	664	207	686	215	668	209	399	126
Industrial	1, 324	325	1, 686	410	1, 586	387	1, 626	396	1, 736	417	2, 262	585
Exports	355	111	515	161	522	163	545	171	575	180	605	188
Total	2, 162	590	3, 024	831	2, 772	757	2, 857	782	2, 979	806	3, 266	899
Total United States:												
Agriculture	8, 470	2, 789	9, 392	3, 090	9, 818	3, 243	10, 535	3, 457	10, 838	3, 553	11, 070	3, 648
Industrial	3, 349	889	3, 816	972	4, 106	1, 047	4, 591	1, 201	4, 475	1, 154	5, 320	1, 424
Exports	2, 724	883	3, 994	1, 290	3, 918	1, 261	3, 934	1, 269	4, 547	1, 480	5, 691	1, 835
Total	14, 543	4, 561	17, 202	5, 352	17, 842	5, 551	19, 060	5, 927,	19, 860	6, 187	22, 081	6, 907

STOCKS

Producers' yearend stocks were 19 percent greater than at the end of 1963.

TABLE 9.—Producer stocks of phosphate rock, December 31

(Thousand long tons)

Source	1963		1964	
	Rock	P_2O_5 content	Rock	P_2O_5 content
Florida	3, 822	1, 263	4, 573	1, 556
North Carolina	------	------	6	2
Tennessee	100	28	82	23
Western States	667	174	806	206
Total	4, 589	1, 465	5, 467	1, 787

PRICES

The Florida land pebble phosphate rock producers, following the action taken by a group of North African producers, raised prices on all grades of phosphate rock approximately 8 percent during the year.

TABLE 10.—Prices of Florida land pebble, unground, washed, and dried phosphate rock, in bulk, carlots, at mine, in 1964

(Per short tons)

Grade (percent B.P.L.)	Jan. 6	Dec. 30
66 to 68	$5.38	[1] $5.84
68 to 70	6.24	[2] 6.76
70 to 72	6.82	[3] 7.38
74 to 75	7.72	[4] 8.34
76 to 77	8.61	[5] 9.30

[1] Quoted at $5.46 per short ton from Mar. 23 to July 6.

[2] Quoted at $6.32 per short ton from Mar. 23 to July 6.

[3] Quoted at $6.70 per short ton from Mar. 23 to Mar. 30, $6.90 from Mar. 30 to July 6.

[4] Quoted at $7.80 per short ton from Mar. 23 to July 6.

[5] Quoted at $8.69 per short ton from Mar. 23 to July 6.

Source: Oil, Paint and Drug Reporter.

FOREIGN TRADE

Nearly all of the superphosphate and ammonium phosphate imports were from Canada. Of the phosphate rock imported, 63 percent came from the Netherlands Antilles, 16 percent from Togo, and 9 percent from Mexico. Belguim and Luxembourg supplied nearly 73 percent of the incoming dicalcium phosphate, and Canada, 27 percent.

TABLE 11.—U.S. imports for consumption of phosphate rock and phosphatic fertilizers

Fertilizer	1963		1964	
	Long tons	Value	Long tons	Value
Phosphates, crude, and apatite	160,708	$3,651,105	155,819	$3,329,309
Phosphatic fertilizers and fertilizer materials	64,144	3,302,069	70,512	4,009,733
Ammonium phosphates, used as fertilizers	115,812	7,244,711	85,845	5,811,974
Bone ash, bone dust, bone meal and bones, crude, steamed, or ground	19,148	1,065,553	10,024	545,238
Manures, including guano	4,594	381,404	3,457	295,516
Basic slag	527	39,073		
Dicalcium phosphate	4,326	210,530	6,291	394,673

Source: Bureau of the Census.

There was an increase of 22 percent in the quantity of phosphate rock exported. Japan, the leading customer, received 28 percent of the exported rock, 5 percentage points more than in 1963.

TABLE 12.—U.S. exports of phosphate rock, by grades and countries

Grade and destination	1963		1964	
	Long tons	Value	Long tons	Value
Florida phosphate rock:				
North America:				
Canada	524,998	$5,253,504	600,710	$6,537,464
Costa Rica	7,243	73,343	11,423	101,240
Dominican Republic	----------	----------	6,795	62,710
El Salvador	3,539	32,616	3,649	34,446
Jamaica	----------	----------	1,284	11,025
Mexico	191,571	1,535,401	200,928	1,639,071
Netherlands Antilles	1,787	14,698	1,990	18,328
South America:				
Brazil	102,726	1,025,440	176,150	1,813,029
Chile	494	10,025	----------	----------
Columbia	16,609	182,791	25,272	211,784
Peru	14,987	147,042	16,153	151,079
Uruguay	----------	----------	15,135	156,273
Venezuela	89	2,116	286	6,781
Europe:				
Belgium-Luxembourg	26,121	225,024	21,161	204,319
Denmark	27,858	253,265	17,134	158,492
Finland	5,297	49,000	12,188	158,519
France	22,329	218,442	25,462	233,482
Germany, West	370,456	3,008,294	779,103	6,063,651
Italy	642,704	5,286,076	714,700	5,788,245
Netherlands	86,905	803,829	77,776	717,472
Norway	6,652	61,517	15,766	145,835
Spain	[r] 74,379	[r] 637,566	122,368	1,056,218
Sweden	51,923	527,350	18,386	188,462
Switzerland	----------	----------	2,358	21,811
United Kingdom	264,579	2,352,353	233,662	2,005,012
Asia:				
Hong Kong	----------	----------	749	6,412
Israel	1,696	11,868	----------	----------
Japan	1,502,333	12,372,072	1,585,779	13,655,797
Malaysia	18,960	297,361	28,643	488,270
Philippines	18,979	190,505	34,513	343,711
Taiwan	10,312	95,527	----------	----------
Viet-Nam, South	23,487	364,196	22,363	354,035
Oceania:				
Australia	26,631	231,280	211,483	2,179,255
New Zealand	----------	----------	102,579	1,024,359
Total	[r] 4,045,644	[r] 35,262,501	5,085,948	45,536,587
Other phosphate rock: [1]				
North America:				
Canada	562,033	5,420,543	551,709	6,968,127
El Salvador	45	803	----------	----------
Guatemala	----------	----------	23	270
Mexico	4,700	34,449	14,145	114,729
Panama	----------	----------	62	700
South America: Venezuela	722	14,645	583	6,970
Europe:				
Belgium-Luxembourg	5,546	43,804	18	200
Germany, West	6,098	55,837	----------	----------
Italy	62	621	----------	----------
Asia:				
Malaysia	----------	----------	49	1,568
Philippines	----------	----------	36	640
Africa: Mozambique	62	542	----------	----------
Total	579,268	5,571,244	566,625	7,093,204
Grand total	[r] 4,624,912	[r] 40,833,745	5,652,573	52,629,791

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[r] Revised.

[1] Includes colloidal matrix, sintered matrix, soft phosphate rock, and Tennessee, Idaho, and Montana rock.

Source: Bureau of the Census.

TABLE 13.—U.S. exports of superphosphates (acid phosphates), by countries

Destination	1963		1964	
	Long tons	Value	Long tons	Value
North America:				
Bahamas	390	$16,460	835	$32,609
British Honduras	----------	----------	80	5,494
Canada	118,508	3,836,506	163,404	5,120,380
Canal Zone	134	7,620	----------	----------
Costa Rica	2,475	146,227	3,695	235,648
Dominican Republic	1,860	69,787	4,104	250,306
El Salvador	110	7,177	6,587	352,445
Guatemala	38	1,920	157	9,079
Honduras	17	1,031	309	21,313
Jamaica	350	23.411	1,753	95,681
Leeward and Windward Islands	5	458	269	15,520
Mexico	6,255	420,941	1,140	85,929
Netherlands Antilles	4	416	6,513	328,416
Nicaragua	531	34,114	581	37,332
Panama	178	13,342	662	43,407
South America:				
Argentina	778	49,070	1,813	127,383
Brazil	46,258	2,494,054	57,137	3,252,015
Chile	81,931	4.660,721	86,307	5,089,761
Colombia	30,618	1,528,870	31,180	1,682.891
Ecuador	420	32,812	2,266	130,991
Peru	37	3,400	295	28,417
Venezuela	3,042	153,693	134	8,187
Other	14	880	515	38,731
Europe:				
Denmark	29	1,000	----------	----------
France	2,003	79,176	16,696	943,060
Germany:				
East	----------	----------	28,709	509,490
West	----------	----------	22,974	726,050
Greece	----------	----------	10,197	569,908
Italy	----------	----------	1,973	105,149
Netherlands	45,005	1,891,235	85,718	4,182,257
Sweden	----------	----------	2,955	141,151
United Kingdom	46	997	----------	----------
Asia:				
Iran	----------	----------	5,167	349,725
Japan	97	7,356	8,259	159,334
Korea, South	255.262	13,486,061	139,189	7,638,468
Nansei and Nanpo Islands	1,012	69,800	3,478	233,812
Philippines	196	13,400	500	35,723
Thailand	880	44,697	----------	----------
Viet-Nam, South	1,606	30,241	45	2,944
Other	7	560	45	3,480
Africa:				
Nigeria	----------	----------	352	22,918
South Africa, Republic of	1,787	92,060	11,921	641,691
Other	4	400	29	1,851
Total	601,887	29,219,893	707,943	33,258,946

Source: Bureau of the Census.

WORLD REVIEW

NORTH AMERICA

Canada.—Border Fertilizer, Ltd., began producing ammonium phosphate and phosphoric acid at a new plant at Winnipeg. The annual production capacity of ammonium phosphate and complex fertilizers was estimated to be about 80,000 tons. Sherritt-Gordon Mines, Ltd., was expanding its Fort Saskatchewan, Alberta, chemical fertilizer facilities. A new phosphoric acid plant with an annual capacity of 44,000 tons of P_2O_5 was included in the project, and production was expected in the summer of 1965. Electric Reduction Co. of Canada Ltd. increased the phosphorus pentoxide capacity of its Port Maitland, Ontario, plant to 100,000 tons per year. Similar increases were made in triple superphosphate production capacities.

El Salvador.—The first chemical fertilizer plant in the country was put on stream at Acajutla by Fertica S.A. Initial annual production rate was stated to be about 18,000 tons of sulfuric acid, 30,000 tons of ordinary superphosphate, and 64,000 tons of mixed fertilizers.

Nicaragua.—Interore International S.A., a subsidiary of Occidental Petroleum Corp., was reported to have joined with local farmers to form Interore de Centro America. The new firm was to build a fertilizer mixing plant having an annual capacity of 75,000 tons.

SOUTH AMERICA

Brazil.—Serrana S.A. de Mineracão Quimica Industrial Brasileira S.A. (Quimbrasil) was constructing a plant to process low-grade ore from its deposits at Jacupiranga, Sao Paulo. Until the plant is completed in 1966, Quimbrasil, a major superphosphate producer with a plant at Sao Caetano do Sud, was expected to import most of its phosphate rock. Fertilizantes Capurava S.A. was reportedly establishing a fertilizer complex in Sao Paulo. The sulfuric acid and superphosphate units were expected to be completed late in the year.

Peru.—The Quimica del Pacifico S.A. dicalcium phosphate plant at Callao began production with an initial daily output of about 25 tons. It was reported that a new company, Minera Bayovar S.A., was formed by Minerales Industriales del Peru S.A., a subsidiary of Medepsa Industries, Ltd. (Montreal), and Texada Mines, Ltd., another Canadian firm, to exploit the extensive phosphate deposits in the Sechura desert.

Venezuela.—International Oil and Fertilizer Corp. a subsidiary of Occidental Petroleum Corp., joined with Corporation Venezolana de Guayana (Government controlled) in planning a large chemical complex which would include facilities for producing elemental phosphorus and phosphates.

TABLE 14.—World production of phosphate rock by countries [1] [2]

(Thousand long tons)

Country [1]	1955-59 (average)	1960	1961	1962	1963	[p] 1964
North America:						
United States	14,547	17,516	18,559	19,382	19,855	22,960
Mexico	[3] 26	27	29	[e] 30	[e] 30	27
Netherlands Antilles (exports)	100	113	150	129	126	[e] 108
Total [1]	14,673	17,656	18,738	19,541	20,011	23,095
South America:						
Argentina (guano)	[4] 1	(5)	(5)	(5)	1	(5)
Brazil:						
Apatite	83	200	240	305	212	[e] 212
Phosphate rock	329	666	409	251	63	[e] 62
Chile:						
Apatite	34	17	14	12	14	12
Guano	30	18	19	16	22	15
Peru (guano)	237	155	157	203	189	202
Venezuela	[4] 44	--------	--------	--------	--------	--------
Total	758	1,056	839	787	501	[e] 503

See footnotes at end of table.

TABLE 14.—World production of phosphate rock by countries[1] [2]—Continued

(Thousand long tons)

Country[1]	1955-59 (average)	1960	1961	1962	1963	1964[p]
Europe:						
Belgium	16	8	14	12	14	[e] 16
France	92	57	80	66	50	[6] 50
Poland	46	40	46	55	64	[6] 64
Spain	6	3	----	----	----	----
U.S.S.R.:						
Apatite [e]	3,810	4,630	5,510	6,500	6,890	7,870
Sedimentary rock [e]	1,730	2,260	3,150	3,350	3,940	4,920
Total [e]	5,700	7,000	8,800	9,980	10,960	12,920
Asia:						
China [e]	250	600	500	600	700	800
Christmas Island (Indian Ocean) (exports)	387	503	694	521	651	775
India (apatite)	11	15	20	29	13	4
Indonesia	2	7	10	6	[e] 6	[e] 6
Israel	149	221	217	207	295	236
Jordan	249	356	416	450	[e] 405	[e] 372
Korea, North (apatite) [e]	30	100	150	200	200	200
Philippines:						
Guano	4	10	(5)	(5)	1	1
Phosphate rock	(5)	(5)	----	4	1	3
Viet-Nam, North:						
Apatite	100	480	555	667	[e] 740	[e] 980
Phosphate rock	33	50	57	33	[e] 49	[e] 49
Total [e] [1]	1,215	2.340	2,620	2,720	3,060	3,430
Africa:						
Algeria	612	554	433	384	343	72
Malagasy Republic	4	5	----	----	----	----
Morocco	5,889	7,354	7,824	8,033	8,413	9,938
Mozambique (guano)	1	(5)	----	----	----	----
Rhodesia (formerly Southern)	(5)	3	(5)	----	----	2
Senegal:						
Aluminum phosphate	92	104	137	139	124	119
Calcium phosphate	1	106	401	489	463	666
Seychelles Islands (guano) (exports)	7	7	8	5	7	4
South Africa, Republic of	179	263	292	302	448	570
South-West Africa (guano)	1	----	1	1	1	(5)
Togo	----	----	116	190	1,051	[7] 766
Tunisia	2,128	2,063	1,950	2,064	2,333	2,708
Uganda (apatite)	3	4	(5)	1	7	[e] 11
United Arab Republic (Egypt)	597	576	617	592	634	591
Total[1]	9,514	11,039	11,779	12,200	13,824	15,447
Oceania:						
Angaur Island (exports)	27	----	----	----	----	----
Australia	7	2	5	4	5	[6] 5
Makatea Island (French Oceania)	293	407	375	312	330	[7] 368
Nauru Island (exports)	1,253	1,351	1,282	1,516	1,547	1,820
Ocean Island (exports)	307	320	338	257	356	323
Total	1,887	2.080	2,000	2,089	2,238	2,516
World total [e] [1] [2]	33,750	41,170	44,780	47,320	50,590	57,910

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[e] Estimate. [p] Preliminary.

[1] A negligible amount of phosphate rock is produced in Jamaica, Japan, Sarawak, Somali Republic, and Tanzania.

[2] This table incorporates some revisions. Data do not add exactly to totals shown because of rounding where estimated figures are included in the detail.

[3] Average annual production 1957-59.

[4] Average annual production 1956-59.

[5] Less than ½ unit

[6] 1963 data.

[7] Exports.

EUROPE

Austria.—A 20,000-ton-per-year phosphoric acid plant was under construction by Progil S.A., a French firm. Also a 120,000-ton-per-year superphosphate plant was under construction. Both plants were expected to be operational in 1965.

Finland.—An apatite mine near Kuuslahti, about 5 kilometers east of Siilinjärvi, was developed by Lohjan Kalkki Oy. Test drillings reportedly revealed that deposits extended over an area about 12 kilometers by 700 meters. Apatite appeared near the surface in some areas so that strip mining may be feasible.

Rikkihappo Oy awarded contracts for the construction of a 30,000-ton-per-year phosphoric acid concentration unit. Included in the contract was provision for the construction of a fluorine recovery plant.

France.—A new phosphoric acid and granular fertilizer plant was under construction near Bayonne by Société Atlantique d'Engrais Chimiques. The annual output capacity was estimated at 30,000 tons of P_2O_5 as acid and 120,000 tons of complex fertilizers. Completion of the project was scheduled for spring 1965.

A new fertilizer producing company was formed by Cie Nord-Africains de l'Hyperphosphate Reno, Ets Kuhlmann, Cie Bordelaise de Produits Chimiques, Soc. des Fertilisants de l'Ouest, and Soc. Chimique de la Grande Paroisse. The new company was to make feasibility studies and to establish a large phosphoric acid plant and fertilizer facilities in the Loire Atlantique region.

Ireland.—An $11.2 million project for the production of sulfuric acid, phosphoric acid, and fertilizers was underway in Dublin. Two U.S. firms, Freeport Sulphur Co. and Texas Gulf Sulphur Co., joined with two Irish firms, W. & H.M. Goulding, Ltd., and Albatros-Windmill Fertilizer Co., to form Phosphac Ltd., which was to operate the phosphoric acid facility.

Rumania.—A phosphoric acid and sodium tripolyphosphate plant purchased from Union Chimique Belge went into production. The rated annual capacity for each product was stated to be 10,000 tons.

U.S.S.R.—The development of a large mine for the production of apatite in the Khibiny Hills in the Kola Peninsula was still in progress. The construction of the mine began 3 years ago, but due to extreme weather conditions, progress was slow. The mine, when completed, will be the largest in the Khibiny Hills, with an expected annual output of 12 million tons of apatite.

Phosphorite deposits found at Gornaya Shoria were estimated to contain 21 million tons. Other deposits found at Kuznetsk Alatau were described by Soviet scientists as the largest known in Siberia.

A contract was awarded to a Belgium firm to build a phosphoric acid plant in the U.S.S.R., to supply the equipment, and to supervise production start up. The designed plant capacity was to be 170 tons per day.

Mining operations were started at the Soviet Union's largest phosphorite deposit of Janatas in the Karatau mountain range in Kazakhstan. Plants for the processing of the ore into fertilizer were under construction in the southern areas of Kazakhstan. The phosphorite reserves were reported to exceed 1,000 million tons.

United Kingdom.—Albright and Wilson Ltd. was modifying its phosphorus furnaces at Portishead, to double their output. The company's furnaces at Oldbury were to be progressively closed down. The modification was to take place over a 2-year period.

What was reported to be the world's largest phosphoric acid reactor went into operation at Imperial Chemical Industries, Ltd., Agricultural Division, works at Billingham. The new reactor replaced the previous system which had required 5 reaction vessels.

Yugoslavia.—A 250,000-ton-per-year superphosphate plant at Kosovska Mitrovica went on stream. Construction of the plant was started in 1960.

ASIA

India.—A list of phosphoric fertilizer plants operating in 1963 was published, including the annual production capacity of each. The total capacity of the 24 plants listed amounted to 530,000 long tons (133,000) tons P_2O_5).[3]

A new company, organized with Albright and Wilson, Ltd., holding a 45 percent interest, was to build a phosphoric acid plant having an annual capacity of 17,500 tons of acid expressed as P_2O_5.

Israel.—Exploration of the Ein Yahav and Meishar deposits was continued by Israel-American Phosphates Co. Reserves suitable for 20 to 30 years of commercial operations were provided.

Deposits of high-grade phosphate rock in the Arad area of southern Israel were discovered by the Geological Institute.

A large chemical complex was planned by Chemicals and Phosphates, Ltd., for the Arad region of Negev, which would include a 100,000-ton-per-year granular fertilizer plant, a 40,000-ton potassium metaphosphate plant, and a 40,000-ton dicalcium phosphate plant.

The same company had a new kiln under construction at its phosphate plant near Oron, for phosphate calcination. The kiln, with an annual capacity of 600,000 tons of calcined phosphates, was scheduled for operation by the end of the year.

Jordan.—The Government purchased the remaining unissued shares of the Jordan Phosphate Co., thus acquiring a majority interest in the company.

The Jordan Phosphate Co. was attempting to contract the mining of an additional 2 million cubic meters of phosphate rock and overburden at Al Hasa. The company expected to produce 200,000 tons of phosphate rock annually from this deposit.

Ralph M. Parsons Co., a U.S. firm, completed the first phase of its contract with the Jordan Development Board for the exploration of the phosphate rock deposits in the Al Hasa area. The existence of 30 million tons of phosphate, averaging 68 percent B.P.L., was established. The company expected to proceed with the designing of mining facilities.

Taiwan.—The Japanese firm, Nippon Kokan KK, was awarded a contract by Taiwan Fertilizer Corp. to design and erect a phosphoric acid plant. The Japanese firm also was to provide technical assistance during the initial operation.

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[3] Bureau of Mines. Mineral Trade Notes. V. 60, No. 1, pp. 40–42.

Turkey.—Under the 5-year plan for expansion of the Turkish superphosphate industry, an annual capacity of 765,000 tons would be required by 1967.

Successful exploration for phosphorite in Turkey by the U.S. Geological Survey under the auspices of the Agency for International Development was reported.[4]

TABLE 15.—Selected African countries: Exports of phosphate rock in 1964, by countries

(Long tons)

Destination	Morocco	Senegal	Togo	Tunisia	Total
North America:					
Canada	31,903	----------	----------	----------	31,903
Cuba	19,536	----------	----------	----------	19,536
United States	7,874	----------	28,018	----------	35,892
South America					
Brazil	----------	----------	20,887	----------	20,887
Chile	9,768	----------	----------	----------	9,768
Uruguay	4,885	----------	13,779	28,542	47,206
Europe:					
Austria	225,803	----------	----------	----------	225,803
Belgium	975,099	----------	27,230	----------	1,002,329
Bulgaria	65,336	----------	----------	69,559	134,895
Czechoslovakia	143,769	----------	----------	70,046	213,815
Denmark	230,162	----------	----------	19,783	249,945
Finland	142,636	----------	----------	----------	142,636
France	1,653,167	----------	128,069	537,466	2,318,702
Germany:					
East	112,983	----------	----------	----------	112,983
West	767,763	213,573	67,060	196,186	1,244,582
Greece	153,146	----------	----------	68,709	221,855
Hungary	107,227	----------	----------	----------	107,227
Ireland	235,438	----------	----------	----------	235,438
Italy	283,808	----------	65,548	464,380	813,736
Netherlands	559,066	61,021	107,943	94,567	822,597
Norway	46,428	----------	22,460	----------	68,888
Poland	507,015	----------	----------	29,841	536,856
Portugal	257,673	----------	----------	----------	257,673
Spain	768,131	----------	----------	137,676	905,807
Sweden	310,296	3,937	----------	28,517	342,750
Switzerland	19,914	----------	----------	3,100	23,014
United Kingdom	779,809	141,726	7,250	34,709	963,494
Yugoslavia	83,571	----------	19,107	164,442	267,120
Asia:					
China	766,115	----------	----------	----------	766,115
India	70,955	----------	----------	203,411	274,366
Japan	210,892	152,553	104,662	30,383	498,490
Taiwan	113,284	----------	----------	----------	113,284
Turkey	4,134	----------	----------	----------	4,134
Africa:					
Canary Islands	19,935	----------	----------	----------	19,935
South Africa, Republic of	----------	[1] 72,832	10,399	----------	83,231
Oceania:					
Australia	----------	56,100	143,537	----------	199,637
Other countries	194,596	----------	----------	----------	194,596
Total	9,882,117	701,742	765,949	2,181,317	13,531,125

[1] Includes Rhodesia.

AFRICA

Morocco.—A large fertilizer plant, to be part of the chemical complex under construction at Safi, was nearing completion. An annual output of 200,000 tons of triple superphosphate and 150,000 tons of diammonium phosphate was expected from the plant when in full operation. A contract was signed by Occidental Petroleum Corp. with the Moroccan Government to build a $25 million phosphoric acid plant.

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[4] Sheldon, Richard P. Exploration for Phosphorite in Turkey—A Case History. Econ. Geol., v. 59, No. 6, September–October 1964, pp. 1159–1175.

The completion date was set for 1965, and the Government and Occidental would be equal partners in the plant. Office Cherifein des Phosphates announced that it would begin to mine the phosphate rock deposit at Meraa-el-Arech, 20 kilometers from Khouribga.

South Africa, Republic of.—Phosphate Development Corp. (Pty.), Ltd. (FOSKOR) completed the expansion program of its facilities at Phalaborwa in order to meet total domestic requirements. Funds for additional expansion to meet increasing demands were approved. W. J. Fraser and Co., Ltd., began construction of a new phosphoric acid plant of 60,000 tons annual capacity at Modderfontein for African Explosives and Chemical Industries Ltd. The company scheduled production for early in 1965.

Southern Rhodesia.—African Explosives and Chemical Industries (Rhodesia) Ltd. began construction on a plant to process phosphate rock mined from the Dorowa deposit. Initial production of 75,000 tons of concentrate was expected for the first year of operation. The plant was to be completed early in 1965.

Tunisia.—Representatives of the Tunisian, Moroccan, and Jordanian phosphate industries met at Tunis on June 14, 1964, and established a new association, Permanent Secretariat of Natural Phosphate Producers. The new association was described as a group open to all phosphate producers and not a marketing agency.[5]

OCEANIA

Australia.—The Minister for National Development announced that the Commonwealth Government wanted the search for domestic phosphate deposits intensified. The Bureau of Mineral Resources located two phosphate areas: One at Rum Jungle and a later discovery in the Amadeus Basin, southwest of Alice Springs, in central Australia, but both of these deposits contained much lower grade rock than that mined at Nauru and Christmas Island. It was stated, however, that these deposits may become commercially important should world prices increase. The Bureau of Mineral Resources started to explore the ocean floor for mineral deposits containing phosphorus. It planned to examine the Continental Shelf during 1965. A 100-ton-per-day phosphoric acid plant was to be erected at Newcastle, New South Wales, for Sulphide Corporation of Australia, Ltd., using the Nissan Chemical Industries Ltd. (Japan) process. The plant was scheduled to go on stream early in 1966.

TECHNOLOGY

The absorption spectra of the apatite and pyromorphite series minerals were studied. It was found that phosphate ions substituted for arsenate ions in mimetite and for vanadate ions in vanadenite could be easily distiguished from phosphate ions present as intergrown pyromorphite by examination of the absorption spectra.[6]

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[5] Bureau of Mines. Mineral Trade Notes. V. 59, No. 5, November 1964, pp. 52–55.

[6] Adler, Hans H. Infrared Spectra of Phosphate Minerals: Symmetry and Substitutional Effects in the Pyromorphite Series. Amer. Miner., v. 49, Nos. 7 and 8, July–August 1964, pp. 1002–1015.

A potentially economic phosphate mineral resource was discovered in the Weaverville Formation near Hyampon in western Trinity County, Calif. Thin bedded tuffaceous shales of Oligocene age that locally contain about 20 percent P_2O_5 have been intruded by a basaltic appearing rock that contains up to 5.2 percent P_2O_5. Geologically, the occurrence created considerable interest because the sediments are continental in origin, whereas phosphate deposits almost universally have been believed to accumulate only in marine basins.[7]

Medium- to low-grade phosphate deposits about 80 feet thick were discovered in an area around Dry Bread Hollow, about 22 miles northeast of Ogden, Utah. The reserve of medium-grade ore (24 to 29.5 percent P_2O_5) was estimated at about 28 million tons and of low-grade (18 to 20.4 percent P_2O_5) ore, about 45 million tons. There was very little grade material, and no estimate of tonnage was made. Underground mining methods would be required to exploit most of the deposits.[8]

It was reported that areas of phosphates with potential commercial possibilities were found on the floor of the Blake Plateau and the Continental Shelf off the South Atlantic coast. A marine geology research team from the Geological Survey and Woods Hole Institute were taking part in a 5-year joint project of exploring the ocean floor for minerals.

The largest excavator ever to be used in phosphate mining was ordered by Texas Gulf Sulphur Co. for operation at its new phosphate mine in eastern North Carolina. The excavator is an electric dragline with a 300-foot boom and a 72-cubic-yard bucket. The equipment was stated to be capable of mining to a depth of 191 feet and discharging the bucket contents up to 580 feet from the digging point.[9]

Victor Chemical Division of Stauffer Chemical Co. awarded a contract to Allis-Chalmers Manufacturing Co. to install a Grate-Kiln system in its new elemental phosphorus plant at Mt. Pleasant, Tenn. The system has been used for producing clinker cement, sintered lime, and iron ore pellets, but this would be its first application for the treatment of phosphate rock.[10]

Bulk shipment of superphosphoric acid was made possible by Union Tank Car Co. with a unique application of a tank car insulation process. The insulated cars were reported to hold the superphosphoric acid at nearly constant temperature over long periods of time without the use of intransit heating.

Multi-Minerals Ltd., Toronto, Canada, continued development of a new method for producing high-grade phosphoric acid economically from mixed apatite-magnetite ore from Ontario. Tests made on a small pilot-plant scale appeared promising. Four advantages were claimed for the new process over the conventional wet-acid process: A better grade acid would result, other phosphate chemicals could be obtained, valuable byproducts would be produced, and the process could be either batch or continuous.[11]

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[7] Lydon, Phillip A. Unusual Phosphite Rock. Calif. Div. of Mines and Geol., Miner. Inf. Service, v. 17, No. 5, May 1964, pp. 65–74.

[8] Work cited in footnote 3.

[9] Mines Magazine. Texas Gulf Sulphur Co. Orders Dragline Excavators for Phosphate Mine in N.C. V. 54, No. 8, August 1964, p. 8.

[10] Chemical & Engineering News. V. 42, No. 51, Dec. 21, 1964, p. 29.

[11] Chemical Engineering. Phosphoric Acid Process Based on Mixed Ore Goes Semicommercial. V. 71, No. 7, Mar. 30, 1964, p. 31.

A new technique for producing superphosphoric acid, developed by Western Phosphates, Inc., and put into operation by International Minerals & Chemical Corp. in its new plant at Bonnie, Fla., was described.[12]

Tennessee Valley Authority was engaged in developing two new processes for producing concentrated wet-process phosphoric acid. One, called the anhydrite process, uses fuming sulfuric acid to react with the phosphate and produces 50 to 55 percent P_2O_5 phosphoric acid. The other, hemihydrate foam method, makes 40 percent P_2O_5 acid by first forming a slurry with finely ground phosphate rock and weak phosphoric acid in a premixer.[13]

Des Plaines Chemical Corp. revealed data on the recovery of byproduct fluosilicic acid in its phosphoric acid plant at Morris, Ill. The figures indicated high efficiency and relatively low cost of operation. This was the first commercial unit to use the new Swift & Co. process to recover phosphoric acid plants.[14]

A comprehensive review of the superphosphate industry including its history, chemistry, and manufacture was published.[15] The book discusses the chemistry and manufacture of superphosphates in considerable detail, providing an excellent reference on the subject.

Volume 1 of a series of volumes dealing with the chemistry of phosphorus compounds and their biological significance was published.[16]

New phosphorus compounds were made available on the market, and new industrial uses were suggested or adopted. Tungsten and molybdenum phosphates were produced by the Chemical and Metallurgical Division of Sylvania Electric Products, Inc.[17] Tri (2-ethylhexyl) phosphate, introduced by FMC Corp., was claimed to impart superior low-temperature properties to vinyl plastics and synthetic rubber compounds.[18] Coalite and Chemical Products, Ltd. (London), offered commercially a new phosphate plasticiser containing 99.9 percent esters and free of phenol. The British Plastics Federation classified the new plasticiser as nontoxic.[19]

A paper was published describing the preparation of light-stable, fire-resistant polyester resins having improved weather resistance. Trialkyl phosphites were shown to react smoothly and exothermally with monoalkyl maleates to produce a colorless liquid composed largely of tetraallylphosphonosuccinate which when subsequently reacted with methyl methacrylate yielded a hard, fire-resistant material. Novel fire-resistant thermosetting compositions were suggested uses for the wide choice of polyphydroxylic compounds available.[20]

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[12] Chemical Engineering. Falling Film Yields Superphosphoric Acid. V. 71, No. 10, May 11, 1964, pp. 94, 96.

[13] Chemical Engineering. Concentrated Phosphoric Acid Again in Limelight. V. 71, No. 26, Dec. 21, 1964, pp. 34–36.

[14] Chemical Week. Fluosilicic Payoff. V. 95, No. 21, Nov. 21, 1964, pp. 96–98.

[15] The U.S. Department of Agriculture and the Tennessee Valley Authority. Superphosphate. U.S. Government Printing Office, Washington, D.C. 1964, 349 pp.

[16] Grayson, Martin, and Edward J. Griffith (eds.). Topics in Phosphorus Chemistry, Volume I. Interscience Publishers Division of John Wiley & Sons, New York, 1964, 262 pp.

[17] Chemical Engineering. V. 71, No. 24, Nov. 23, 1964, p. 98.

[18] Chemical Engineering. V. 71, No. 12, June 8, 1964, p. 110.

[19] Chemical Trade Journal and Chemical Engineer (London). "Non-toxic" Phosphate Plasticiser. V. 155, No. 4024, July 24, 1964, p. 117.

[20] Hindersinn, Raymond R., and Nicodemus E. Boyer, Phosphorus—Containing Unsaturated Polyester Resins From Trialkyl Phosphates. Prod. Res. & Redevel.: Ind. & Eng. Chem., v. 3, No. 2, June 1964, pp. 141–145.

Turco Products, Inc., Wilmington, Calif., exhibited a new phosphate coating process which was claimed to cut painting costs up to 30 percent and promote maximum paint adhesion.[21] A new process for coating iron and steel using zinc phosphate was developed by Parker Rust Proof Division, Hooker Chemical Corp. The process was stated to provide 6 to 10 times greater rust resistance than the conventional coating processes.[22]

Patents were granted for new methods and techniques for beneficiating [23] and processing phosphate rock,[24] for the recovery of byproducts,[25] for further treatment of phosphoric acid,[26] and for phosphate surface coatings.[27] Space limitation prohibits citing the many patents issued for the preparation of a large variety of phosphorus compounds.

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[21] Metal Progress. V. 86, No. 5, Nov. 1964, pp. 7, 8.

[22] Materials in Design Engineering. Zinc Phosphate Beats Plant in Salt Bout. V. 59, No. 2, February 1964, pp. 150, 152.

[23] Seymour, James E., and Robert White (assigned to Armour & Co., Chicago, Ill.). Treatment of Phosphate Rock. U.S. Pat. 3,150,957, Sept. 29, 1964.

[24] Barber, James C., George H. Megar, and Thomas S. Sloan (assigned to the Tennessee Valley Authority). Recovery of Phosphorus From Sludge. U.S. Pat. 3,136,604, June 9, 1964.

Fallin, Earl A. Production and Purification of Phosphatic Materials. U.S. Pat. 3,161,466, Dec. 15, 1964.

Gilchrist, James G., Jr. (assigned to International Minerals & Chemical Corp.). Method for the Production of Phosphoric Acid. U.S. Pat. 3,122,415, Feb. 25, 1964.

Hignett, Travis P., Archie V. Slack, John M. Potts, and Larrabee D. Hand, Jr. (assigned to the Tennessee Valley Authority). Direct Method for the Production of High-Analysis Phosphoric Acid. U.S. Pat. 3,161,467, Dec. 15, 1964.

Hollingsworth, Clinton A., Louis J. Lamb, and Wiley C. Austin (assigned to Smith-Douglass Co., Inc., Norfolk, Va.). Process for the Defluorination of Phosphates. U.S. Pat. 3,151,936, Oct. 6, 1964.

Hollingsworth, Clinton A., Louis J. Lamb, and Wiley C. Austin (assigned to Smith-Douglass Co., Inc., Norfolk, Va.). Defluorination of Phosphoric Acid. U.S. Pat. 3,151,941, Oct. 6, 1964.

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Nickerson, John D. (assigned to International Minerals & Chemical Corp.). Manufacture of Defluorinated Phosphates. U.S. Pat. 3,142,534, July 28, 1964.

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[25] Yamaguchi, Taro (assigned to Onoda Cement Co. Ltd., Onoda, Japan). Method of Improving the Grade of Byproduct Gypsum Obtained in Carrying Out a Wet Process for Production of Phosphoric Acid. U.S. Pat. 3,159,497, Dec. 1, 1964.

[26] Barton, Charles J., and James E. Lawver (assigned to International Minerals & Chemical Corp.). Method for Determining the Phosphate Content of Phosphatic Materials. U.S. Pat. 3,137,543, June 16, 1964.

Geld, Isidore, and Sidney Tudor (assigned to the United States of America as represented by the Secretary of the Navy). Method of Determining the Concentration of Phosphoric Acid in a Solution. U.S. Pat. 3,125,419, Mar. 17, 1964.

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[27] Fuchs, Robert J. (assigned to FMC Corp., New York). Sodium Phosphate Glasses. U.S. Pat. 3,130,002, Apr. 21, 1964.

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Platinum-Group Metals

By Glen C. Ware[1]

⁂

PLATINUM-GROUP METALS were traded on a seller's market in 1964 in spite of a significant increase in world production. The output of Canada increased 5 percent, and that of South Africa is estimated to have doubled to bring the year's increase in free world production to more than 300,000 ounces. The increase in the production of the U.S.S.R. is difficult to conjecture. If the estimated output of the free world is compared with the amount of metal estimated to have reached world markets, it becomes apparent that production in the U.S.S.R. has expanded to the point that it equals the production of the rest of the world.

Prices rose for all metals of the group except ruthenium. The free market price of platinum rose to $137 to $140 an ounce, although the two major suppliers allocated the metal to their customers at $87 to $90 throughout the year after January 6.

The United States, which consumes about one-half of the world's production of platinum-group metals, increased its imports by 17 percent and its consumption by 14 percent. The free world increased its production by 41 percent, indicating that supply may satisfy demand over the near term. Declining future prices at the end of the year lend credence to this inference.

TABLE 1.—Salient platinum-group metals statistics

(Troy ounces)

	1955–59 (average)	1960	1961	1962	1963	1964
United States:						
Mine production[1]	18,589	23,609	43,248	28,742	49,750	40,487
Value	$1,368,344	$1,485,439	$2,256,432	$1,591,463	$2,442,840	$2,395,877
Refinery production:						
New metal	52,975	51,243	79,453	54,775	80,208	71,090
Secondary metal	95,127	76,857	85,971	132,102	117,099	120,147
Imports for consumption	881,319	680,646	884,463	720,352	[r] 1,003,608	1,173,615
Exports (except manufactures)	38,033	65,149	61,845	60,591	63,012	146,306
Stocks Dec. 31: Refiner, importer, dealer	512,817	515,750	555,445	598,102	699,575	767,264
Consumption	807,969	775,214	823,226	866,459	1,003,194	1,139,970
World: Production	1,095,000	1,275,000	1,355,000	1,635,000	1,545,000	2,050,000

[r] Revised.

[1] From crude platinum placers and byproduct platinum-group metals recovered largely from domestic gold and copper ores.

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[1] Commodity specialist, Division of Minerals.

Legislation and Government Programs.—There were no changes in the Government inventories of platinum-group metals. The stockpile objective for platinum was increased to 450,000 ounces from 165,000 ounces, the objective for palladium was raised from 340,000 ounces to 1.3 million, and the objective for iridium was increased from 4,000 to 17,000 ounces. A review is being made of the need to set objectives for osmium, rhodium, and ruthenium.

TABLE 2.—Government inventory of platinum-group metals, December 31, 1964

(Thousand troy ounces)

Metal	National (strategic) stockpile	Supplemental stockpile	Total
Iridium	14		14
Palladium	90	648	738
Platinum	716	50	766
Rhodium	1		1
Ruthenium		15	15
Total	821	713	1,534

DOMESTIC PRODUCTION

The Goodnews Bay Mining Co. produced platinum-group metals from placer deposits. Recovery from sludge and residue was reported by American Metal Climax, Inc., American Smelting and Refining Company, and International Smelting & Refining Co. Yuba Consolidated Industries, Inc., recovered some crude platinum from its gold placer operation.

Toll refining increased 20 percent to 1.114 million ounces for the group. Platinum constituted 67 percent of the refined metal, the major part of which was recovered from spent catalysts used in oil refining and in the manufacture of nitric acid. Second in amount was palladium, 326,000 ounces of which was recovered. The supply of platinum from toll refining exceeded that of new metal, illustrating the nondissipative character of its use. Of the minor metals, 33,000 ounces of rhodium, 3,814 ounces of iridium, 1,456 ounces of ruthenium, and 726 ounces of osmium were returned to the users by toll refiners.

TABLE 3.—New platinum-group metals recovered by refiners in the United States, by sources

(Troy ounces)

Year and source	Platinum	Palladium	Iridium	Osmium	Rhodium	Ruthenium	Total
1955–59 (average)	42,468	5,596	2,414	809	780	908	52,975
1960	35,131	9,636	2,675	1,003	2,457	341	51,243
1961	46,113	28,988	1,903	148	1,993	308	79,453
1962	36,462	16,144	905	100	1,016	148	54,775
1963:							
From domestic sources:							
Crude platinum Gold and copper refining	20,818	28,099	1,381	189	1,073	398	51,958
From foreign crude platinum	19,472	4,700	889	----------	2,348	841	28,250
Total	40,290	32,799	2,270	189	3,421	1,239	80,208
1964:							
From domestic sources:							
Crude platinum Gold and copper refining	15,608	22,863	2,423	366	2,757	286	44,303
From foreign crude platinum	14,931	4,438	1,558	149	3,517	2,194	26,787
Total	30,539	27,301	3,981	515	6,274	2,480	71,090

TABLE 4.—Secondary platinum-group metals recovered in the United States

(Troy ounces)

Year	Platinum	Palladium	Iridium	Osmium	Rhodium	Ruthenium	Total
1955–59 (average)	47,642	40,471	1,413	354	3,259	1,988	95,127
1960	38,861	35,465	914	279	953	385	76,857
1961	51,218	32,451	193	6	1,836	267	85,971
1962	71,817	56,273	767	99	2,570	576	132,102
1963	54,084	59,993	440	273	1,990	319	117,099
1964	66,043	49,879	764	928	2,338	195	120,147

CONSUMPTION AND USES

The use of all the metals of the group in the petroleum industry increased spectacularly; the use of platinum trebled and that of palladium more than doubled. The use of 2,000 ounces each of rhodium and ruthenium in the oil industry signals a change in technology or production in that industry, since it had consumed no ruthenium and only a small amount of rhodium in the past. It is noteworthy that, despite a 93-percent increase in the consumption of ruthenium, its price did not change.

An 81-percent increase in the use of rhodium in the glass industry may have reflected its application in prolonging the life of iridium vessels in which the materials for laser crystals are melted.

TABLE 5.—Platinum-group metals sold to consuming industries in the United States

(Troy ounces)

Year and industry	Platinum	Palladium	Iridium	Osmium	Rhodium	Ruthenium	Total	Percent of total
1955–59 (average)	374,573	400,422	6,160	881	20,725	5,208	807,969	100
1960	324,583	414,225	6,168	788	24,615	4,835	775,214	100
1961	283,088	508,040	6,547	805	19,174	5,572	823.226	100
1962	304,272	519,860	9,251	1,125	26,063	5,888	866,459	100
1963:								
Chemical	156,427	118,757	3,860	930	9,537	1,068	290,579	29
Petroleum	40,721	16,008	----------	----------	188	1	56,918	6
Glass	57,919	20	50	----------	13,191	2	71,182	7
Electrical	110,576	331,868	2,364	19	6,676	888	452,391	45
Dental and medical	18,894	42,940	102	----------	10	469	62,415	6
Jewelry and decorative	32,963	13,880	3,302	----------	7,044	492	57,681	6
Miscellaneous	6,844	3,054	154	107	422	1,447	12,028	1
Total	424,344	526,527	9,832	1,056	37,068	4,367	1,003,194	100
1964:								
Chemical	137,248	117,102	2,659	1,157	13,179	2,636	273,981	24
Petroleum	130,981	41,887	88	100	2,121	2,018	177,195	16
Glass	49,680	110	6	----------	23,923	----------	73,719	6
Electrical	103,584	350,889	2,288	23	7,687	1,049	465,520	41
Dental and medical	19,376	49,893	198	----------	38	862	70,367	6
Jewelry and decorative	29,576	20,886	4,354	----------	8,296	793	63,905	6
Miscellaneous	3,195	10,665	59	99	182	1,083	15,283	1
Total	473,640	591,432	9,652	1,379	55,426	8,441	1,139,970	100

TABLE 6.—Refiner, importer, and dealer stocks of platinum-group metals in the United States, December 31, 1964

(Troy ounces)

Year	Platinum	Palladium	Iridium	Osmium	Rhodium	Ruthenium	Total
1960	260,916	204,345	11,473	4,225	26,547	8,244	515,750
1961	255,654	244,910	12,250	3,058	29,258	10,315	555,445
1962	256,755	285,173	13,871	2,762	30,692	8,849	598,102
1963	320,601	315,756	18,907	1,531	32,900	9,880	699,575
1964	378,896	317,691	20,022	1,936	38,388	10,331	767,264

PRICES

The price of platinum increased moderately during the year. Producers allocated it to established customers at $87 to $90 per ounce after an increase from $82 to $85 in January. Dealers' prices, however, moved up from $98 per ounce in February to $133 in June, to $143 in August, and down to $140 by the end of the year. Seven increases in the price of palladium raised it from $24 to $26 at the beginning of the year to $32 to $34 in December. By midyear the price of iridium had increased from $70 to $75 per ounce to $90 to $95, where it remained steady. The price of osmium virtually tripled, increasing from $60 to $80 per ounce to $190 to $200 during the year. A series of increases raised the price of rhodium from $137 to $140 per ounce to $182 to $185. The price of ruthenium remained at $55 to $60 throughout the year.

Futures for platinum, which were near $105 per ounce at the beginning of the year, increased to $148, but they eased later to prices which ranged around $135 an ounce, with lower quotations for deliveries in 1966.

FOREIGN TRADE

The United States imports of platinum-group metals reached an alltime high. Canada supplied 557,000 ounces, 47 percent of the total. Since Canadian production was only 375,000 ounces, a great deal of its supply was reexported metal.

United States exports to various countries have fluctuated widely. In 1964 significant increases were noted for Japan, the United Kingdom, the Federal Republic of Germany, and France. The United Kingdom again took more than one-half of U.S. exports.

The value of exports of platinum-group manufactures reached an alltime high of more than $5 million, excluding jewelry.

TABLE 7.—U.S. imports for consumption of platinum-group metals

Year	Troy ounces	Value (thousands)	Year	Troy ounces	Value (thousands)
1955–59 (average)	881,319	$40,717	1962	720,352	$32,699
1960	680,646	34,131	1963	1,003,608	50,376
1961	884,463	36,840	1964	1,173,615	50,539

[r] Revised.

Source: Bureau of the Census.

TABLE 8.—U.S. imports for consumption of platinum-group metals (unmanufactured), by countries [1]

(Troy ounces)

Year and country	Unrefined material		Refined metals					
	Platinum grain nuggets (including crude dust and residues)	Platinum sponge and scrap	Platinum	Palladium	Iridium	Rhodium	Ruthenium	Total
1963:								
North America:								
Canada	29		r 64,526	33,482	9,625	5,625	800	r 114,087
Mexico		1,764		3,582		5		5,351
Netherlands Antilles	350							350
Panama	1,037							1,037
South America: Colombia	r 29,453							r 29,453
Europe:								
Belgium-Luxembourg			249	5,700				5,949
France			35	4,297				4,332
Germany, West			354			129		483
Italy			r 2,043			30		r 2,073
Netherlands			(r)	r 10,829				10,829
Norway	1,200		2,975	4,075	r 154	r 334	r 279	r 9,017
Spain			85					85
Sweden			1,203					1,203
Switzerland			r 51,948	128,717		1,648		r 182,313
U.S.S.R.	3,468		28,930	185,897		12,560		230,855
United Kingdom	15,891		r 229,337	127,064	r 3,437	r 16,530	3,117	[2] 397,467
Asia:								
Japan	64	4,512		1,711				6,287
Jordan			r 115					r 115
Lebanon	60		121					181
Taiwan				95				95
Africa:								
Mozambique			675					675
South Africa, Republic of		900						900
Oceania: Australia		471						471
Total:								
Troy ounces	r 51,552	7,647	r 382,596	r 505,449	r 13,216	r 36,861	r 4,196	r 1,003,608
Value	$3,756,942	$560,096	r $28,969,082	r $11,088,204	r $969,884	r $4,850,704	r $181,086	r $50,375,998

1964:								
North America:								
Canada			432,317	95,084	4,060	24,449	1,465	557,375
Honduras		132						132
Mexico			954	1,406				2,360
Netherlands Antilles		272						272
South America: Colombia	22,166	1,115		64				23,345
Europe:								
Belgium-Luxembourg		202		8,075				8,277
Czechoslovakia						416		416
France			18	1,179				1,197
Germany, West	432		612	10,271		148		11,463
Italy		84		3,049				3,133
Netherlands	517			45,011		1,003		46,531
Norway	2,600		4,406	7,369	510	1,293	988	17,166
Switzerland			6,831	72,656		9,889		89,376
U.S.S.R.	1,649	2,095	6,351	126,719		7,092		[2] 145,519
United Kingdom	8,552		126,693	93,595	2,045	11,514	7,903	[2] 252,636
Asia:								
Japan		1,227	306	12,720				14,253
Lebanon			164					164
Total:								
Troy ounces	35,916	5,127	578,652	477,198	6,615	55,804	10,356	1,173,615
Value	$3,341,061	$486,947	$24,365,568	$13,300,205	$488,621	$7,955,125	$403,745	$50,538,931

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[r] Revised.

[1] Certain items reported by the Bureau of the Census as "sponge and scrap" have been reclassified by the Bureau of Mines and included with "platinum refined metal" in this table.

[2] Includes 2,091 ounces ($49,715) of osmium imported in 1963; 1,399 ounces ($113,039) of osmium and 935 ounces ($34,793) of osmiridium imported from the United Kingdom and 1,613 ounces ($49,827) of osmiridium from the U.S.S.R. in 1964.

Source: Bureau of the Census

TABLE 9.—U.S. exports of platinum-group metals, by countries

Year and destination	Platinum (ore, concentrates, ingots, bars, sheets, wire, sponge, and other forms, including scrap)		Palladium, rhodium, iridium, osmiridium, ruthenium, and osmium (metal and alloys including scrap)		Platinum group manufactures, except jewelry (value)
	Troy ounces	Value	Troy ounces	Value	
1955–59 (average)	22,346	$1,479,630	15,687	$449,432	$2,013,305
1960	49,497	3,211,538	15,652	503,914	2,978,436
1961	41,385	2,088,753	20,460	819,882	2,983,447
1962	49,651	1,514,082	10,940	458,924	4,105,734
1963:					
North America:					
Canada	338	54,912	1,200	50,373	1,507,270
Mexico	142	15,300	3,857	105,891	299,715
Netherlands Antilles	1,285	99,190	------	------	80,914
Other	2	298	257	5,941	47,107
South America:					
Brazil	1,647	175,960	545	15,411	2,478
Chile	41	4,112	15	2,436	1,241
Colombia	14	2,021	64	1,376	3,955
Other	------	------	12	1,489	6,490
Europe:					
Belgium-Luxembourg	345	32,318	321	14,480	29,297
France	6,472	532,428	1	258	14,484
Germany, West	6,882	576,758	3,080	100,111	28,240
Italy	377	30,821	446	55,262	7,434
Switzerland	2,783	248,879	146	7,033	6,232
United Kingdom	26,684	1,517,262	313	26,554	74,206
Other	1,243	97,414	72	1,989	5,172
Asia:					
India	321	24,000	------	------	5,002
Japan	2,564	227,311	1,447	118,890	56,301
Other	94	9,930	------	------	32,720
Africa	------	------	------	------	31,934
Oceania	2	1,440	------	------	15,409
Total	51,236	3,650,354	11,776	507,494	2,255,601
1964:					
North America:					
Canada	946	111,784	8,578	466,509	2,622,011
Mexico	145	15,030	3,193	184,004	208,010
Netherlands Antilles	1,310	176,123	48	9,645	32,137
Other	5	682	28	3,794	68,005
South America:					
Brazil	1,560	255,757	38	6,859	22,841
Chile	13	840	------	------	3,391
Colombia	301	28,325	70	4,552	115,595
Other	32	13,898	151	9,742	104,883
Europe:					
Belgium-Luxembourg	750	86,638	426	22,679	94,265
France	9,051	872,108	248	32,081	153,213
Germany, West	16,097	1,836,392	4,817	274,965	168,737
Italy	5,370	466,113	396	34,999	654
Switzerland	1,599	171,827	104	6,936	181,886
United Kingdom	64,367	2,789,851	752	66,207	169,746
Other	531	57,330	60	6,886	53,632
Asia:					
India	86	9,450	30	2,244	9,141
Japan	22,924	2,947,723	2,208	226,920	804,059
Other	18	1,332	20	3,580	25,389
Africa	------	------	------	------	7,041
Oceania	34	1,114	------	------	238,788
Total	125,139	9,842,317	21,167	1,362,602	5,083,424

Source: Bureau of the Census.

WORLD REVIEW

Estimates of the production of platinum-group metals in the free world were 745,000 ounces in 1963 and 1.050 million ounces in 1964, an increase of 41 percent. Free world use is not reported, but the major part of it is represented by U.S. consumption, which increased 14 percent. This disparity indicates the possibility that free-world stocks may have been increased. Iron-curtain consumption and production are speculative, but there is evidence that production in the Soviet Union has been increasing in step with demand.

TABLE 10.—World production of platinum-group metals

(Troy ounces)

Country	1955-59 (average)	1960	1961	1962	1963	[p] 1964
North America:						
Canada:						
Platinum: Placer and from refining nickel-copper matte	163,587	483,604	418,278	470,787	357,651	374,988
Other platinum-group metals: From refining nickel-copper matte	185,273					
United States:						
Placer platinum and from domestic gold and copper refining	18,589	23,609	43,248	28,742	49,750	40,487
South America:						
Colombia:						
Placer platinum [1] (U.S. imports)	32,150	31,943	32,938	23,643	29,453	23,345
Europe:						
U.S.S.R. [e]	260,000	330,000	500,000	800,000	800,000	1,000,000
Asia:						
Japan:						
Palladium from refineries	251	563	1,550	1,372	1,326	1,875
Platinum from refineries	475	1,396	2,247	1,872	1,714	2,199
Iridium from refineries	776	-----	-----	-----	-----	-----
Africa:						
Ethiopia:						
Placer platinum	196	189	180	180	[e] 180	[e] 180
South Africa, Republic of:						
Platinum-group metals from platinum ores	429,002	[e] 400,000	[e] 350,000	[e] 300,000	[e] 300,000	[e] 600,000
Osmiridium from gold ores	5,861	[2] 6,334	[e] 7,000	[e] 6,000	[e] 5,500	[e] 6,000
World total (estimate) [3]	1,095,000	1,275,000	1,355,000	1,635,000	1,545,000	2,050,000

[p] Preliminary.
[e] Estimate.
[1] Also includes small amounts of sponge and scrap.
[2] Sales.
[3] Includes small quantities from Philippines, Congo (Léopoldville), Australia, and New Guinea.

Canada.—Canada increased its output of platinum-group metals 5 percent compared with a 7 percent increase in the production of nickel. This disparity reflects the lower precious metal content of the nickel ore from the newly developed mines in Manitoba which are producing an increasing proportion of Canada's nickel output.

Colombia.—The International Mining Corp. reported the production of 12,300 ounces of platinum-group metals in 1964. Its subsidiary, the Choco-Pacifico Mining Co., operated four dredges in the Department of Choco.

Japan.—Japan was an important user of platinum-group metals, having imported 376,000 ounces in 1963. Complete reports for 1964 are not available, but imports of platinum ingots were down 27 percent from 220,000 ounces in 1963. Japan produced 1,700 ounces of platinum-group metals in 1963 and 2,200 ounces in 1964.

South Africa, Republic of.—The output of platinum-group metals in the Republic of South Africa continued to expand, reaching the limit of mine capacity, estimated to be about 600,000 ounces compared with about 300,000 ounces of production in 1963. Placer gold mining contributed about 6,000 ounces of osmiridium. Rustenburg Platinum Mines Ltd. reported plans for a 25 percent increase in capacity and later announced that the increase would be 40 percent. The expansion was expected to be completed during the first half of 1966, but the initial output from the expansion should reach the market by late 1965.

Rustenburg Platinum Mines Ltd. concluded an agreement with a consortium of South African mining interests to supply the consortium with its platinum requirements for a period of 20 years in return for mining rights in the neighboring Brakspruit property. The consortium, in turn, has contracted the Engelhard Industries International Ltd., a Canadian company, to dispose of this supply of metal.

U.S.S.R.—The production of platinum-group metals by the U.S.S.R. can only be inferred from indirect data. Estimates based upon the amount of metal reaching world markets during the period 1961 through 1963 indicate that the output of the U.S.S.R. was increasing and probably amounted to 1 million ounces in 1964. It is believed to have come chiefly from ore mined in the Norilsk region where deposits were known to exist, but which were not exploited until after World War II. Reportedly, the fertilizer industry in the U.S.S.R. has fallen short of goals and has not required platinum-group metals in the amounts predicted.

TECHNOLOGY

The technology of the platinum-group metals advanced on a broad basis, with significant developments being made both in applications and in fundamental knowledge. Improved stability, higher operating temperatures, and increased mechanical strength were achieved in thermocouples by making both legs of Pt-Rh alloy. The National Bureau of Standards determined that a 50 iridium-50 rhodium alloy versus iridium gave 12.2 millivolts at 2,150° C. and may be the optimum combination of these metals. The Bureau prepared a reference table for a series of thermocouples of this type.[2] When a thermocouple catalyzes a chemical reaction in the medium under observation, it may become heated. Temperatures 100° F. above ambient have been observed on a platinum versus platinum-15 percent iridium thermocouple.

Electrochemical oxidation produces the potential of fuel cells. When methanol was oxidized on platinized Raney nickel, it produced 400 milliamperes per square centimeter at potentials up to 0.85 volt. The energy-to-weight ratio was several times higher than for unplatinized electrodes.[3] A current of 200 milliamperes was produced by oxidizing ethane, propane, butane, ethylene, and carbon monoxide with platinized Raney nickel. Platinized waterproofed acrylic paper electrodes in fuel cells compare favorably with screen supported platinum black electrodes.

The selectivities of each of the platinum-group metals as catalysts to hydrogenate acetylene, allene, 1,3-butadiene, and dimethylacetylene were shown to increase through the two series, Ru, Rh, and Pd; and Os, Ir, and Pt. Each metal of the first series was more selective than its counterpart in the second series.[4] Palladium proved to be superior to 13 other metals in catalyzing the combustion of methane. It was proposed to prepare hydrogen for use in fuel cells by diffusing it from a mixture with carbon monoxide in a coiled tube of palladium-silver alloy. The carbon monoxide is burned to provide heat to convert methanol and steam to hydrogen and carbon monoxide.

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[3] Boies, David B., and Andrew Dravnieks. New High-Performance Methanol Fuel Cell Electrodes. Electrochem. Tech., v. 2, No. 11–12, November–December 1964, pp. 351–354.

It has been made possible to catalyze chemical reactions with specific molecular species by use of natural or synthetic zeolitic materials whose crystal pore size excludes unwanted molecules from the platinum containing catalyst.

The oxidation of several organic compounds at a platinum anode were reported.[5] The relative electrocatalytic activity of platinum, rhodium, and iridium in the oxidation of ethylene decrease in the order given. Palladium was more active than gold.[6]

To test their usefulness as coatings, iridium and ruthenium were contacted with molten metals heated 50° C to 200° C above their melting points in an atmosphere of argon. Both were unattacked by lithium, sodium, potassium, silver, gold, mercury, indium, lead, and bismuth. Iridium was attacked by cadmium, gallium, tin, and tellurium, and both were attacked by calcium, magnesium, aluminum, and antimony. At higher temperatures ruthenium dissolved slightly in bismuth.[7] The vapor pressures and heats of sublimation of ruthenium and osmium were measured by a microbalance technique. Free energy functions were used to calculate the heats of sublimation.[8]

The effect of ordering in cobalt-chromium-platinum alloys was studied as an initial step in the evaluation of their magnetic properties.[9] Rhodium was shown to form a complete series of solid solutions with nickel, but with copper there is a miscibility gap between solutions containing 10 atomic percent and 80 atomic percent copper.[10]

The ultimate tensile strength and the yield strength of polycrystalline silver-palladium alloys increases with increase in silver content up to 25 percent silver.[11] A series of spinels containing rhodium instead of chromium have been shown to be normal and isomorophous with chrome spinels.[12]

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[7] Rhys, D. W., and E. G. Price. Resistance of Iridium and Ruthenium to Liquid Metal Attack. Metal Ind. (London), v. 105, No. 8, Aug. 20, 1964, pp. 243–245, 247.

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[10] Journal of Less-Common Metals (Netherlands). Solid Solutions of Rhodium With Copper and Nickel. V. 6, No. 3, March 1964, pp. 248–249.

[11] Journal Institute of Metals (London). Yield-Strength Variation in Polycrystalline Silver-Palladium Alloys. V. 93, Pt. 3, November 1964, p. 96.

Tests of nickel alloys containing 0.5, 2.0, and 6.0 atomic percents of palladium, rhodium, ruthenium, and osmium showed that the tensile strength and stress-rupture life increased in the above order when the same atomic percents of admixture were compared. The ductility decreased with increasing concentration or with the temperature for a given concentration.[13] Mass transport occurs in platinum powder compacts only when a reactive gas such as hydrogen is present. It is that movement of metal during sintering which accounts for the densification of compacts.

Iridium alloyed with 5 percent tungsten was made into springs which resisted relaxation when heated to 700° C for extended periods. It had good tensile strength and a high Young's modulus.

A method was devised to calculate the surface area of platinum deposited on carbon, eliminating errors caused by diffusion of hydrogen into the carbon.

Patents were issued for magnetic alloys containing platinum-group metals,[14] palladium-base alloys,[15] and the preparation of catalysts containing platinum-group metals.[16]

Patents were issued for the reactivation and protection of catalysts,[17] and the chemical processes using platinum-group metal catalysts, six of which were related to petroleum refining.[18] Patents were issued for processes to recover platinum-group metals,[19] electrodeposition of palladium,[20] deposition of ruthenium,[21] and immersion plating.[22] Patents were granted for a method to convert heat into electricity,[23] a method to make composite metal products,[24] simultaneous brazing and corrosion-protecting refractory metals,[25] and for alloys to dope semiconductor materials.[26]

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Potash

By Richard W. Lewis[1]

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THE YEAR 1964 was memorable for the potash industry. The first successful production of potash by solution mining was a major breakthrough in potash mining technology. Increased world demand for fertilizers pushed production and sales to new records and accelerated exploration, expansion, and new construction:

DOMESTIC PRODUCTION

The record production of nearly 5 million short tons of marketable potassium salts was almost 2 percent greater than in 1963. California and New Mexico were responsible for the increase, while Utah production declined slightly. Output by byproduct producers in Michigan and Maryland remained at about the same level. Again 90 percent of domestic production came from the Carlsbad, N. Mex., area.

The calculated average grade of crude salts mined in New Mexico was 17.98 percent potassium monoxide (K_2O) equivalent, compared with 18.78 percent in 1963.

Approximately 12,000 tons of manure salts, equivalent to 2,860 tons of K_2O, was produced and sold.[2]

Exploration for domestic potash continued active all year. Tenneco Oil Co. and Richfield Oil Co. were engaged in drilling and evaluation studies in Utah. Tenneco was drilling in the Redd Ranch area of San Juan County, while Richfield was working in the vicinity of the uranium development of the Monte Cristo Corp. southwest of Moab.

Foote Mineral Corp. was preparing for mining operations at the Silver Peak dry lakebed in Clayton Valley near Tonopah, Nev. Leases on 15,000 acres of Government land were acquired from Leprechaun Mining & Chemical Co. for a guaranteed share of the ultimate profits resulting from the mining venture. Plans called for pumping brine from the huge salt water lake underlying the area into solar evaporating ponds. Initially, potassium, lithium, and rubidium would be recovered. It was reported that the company planned to lease at least 50 square miles in the area for possible future development.

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[1] Commodity specialist, Division of Minerals.

[2] American Potash Institute, Inc. North American Deliveries of Potash Salts. E-178, Mar. 17, 1965. (May contain some Canadian production.)

TABLE 1.—Salient potash statistics

(Thousand short tons and thousand dollars)

	1955–59 (average)	1960	1961	1962	1963	1964
United States:						
Production of potassium salts, marketable quantity	3,741	4,472	4,629	4,167	[r]4,871	4,954
Approximate K_2O equivalent quantity	2,207	2,638	2,732	2,452	[r]2,864	2,897
Value [1]	$80,143	$89,676	$104,464	$94,859	[r]$110,164	$114,100
Sales of potassium salts by producers quantity	3,749	4,412	4,226	4,615	[r]4,587	5,201
Approximate K_2O equivalent quantity	2,212	2,602	2,487	2,722	[r]2,709	3,045
Value at plant	$80,210	$88,417	$95,388	$105,608	[r]$103,828	$120,284
Average value per ton	$21.40	$20.04	$22.57	$22.89	[r]$22.64	$23.13
Imports for consumption of potash materials quantity	360	415	465	617	1,041	1,259
Approximate K_2O equivalent quantity	195	226	262	341	594	738
Value	$12,844	$15,370	$17,315	$21,765	$31,137	$36,044
Exports of potash materials quantity	435	833	803	859	722	1,048
Approximate K_2O equivalent quantity	236	491	473	506	425	618
Value	$15,684	$25,926	$32,477	$30,731	$25,519	$37,586
Apparent consumption of potassium salts [2] quantity	3,674	3,994	3,888	4,373	[r]4,906	5,412
Approximate K_2O equivalent quantity	2,171	2,337	2,276	2,557	[r]2,878	3,165
World: Production, marketable: Approximate K_2O equivalent quantity	8,700	10,000	10,700	10,800	12,100	13,000

[r] Revised.

[1] Derived from reported value of "Sold or used."

[2] Measured by sold or used plus imports minus exports.

TABLE 2.—Production and sales of marketable potassium salts in the United States, in 1964, by product

(Thousand short tons and thousand dollars)

Product	Production			Sales		
	Gross weight	K_2O equivalent	Value [1]	Gross weight	K_2O equivalent	Value
Muriate of potash, 60-percent K_2O minimum:						
Standard	2,188	1,341	$46,773	2,311	1,417	$49,550
Coarse	1,486	906	34,558	1,576	961	36,847
Granular	573	346	13,857	569	343	13,819
Total	4,247	2,593	95,188	4,456	2,721	100,216
Other potassium salts [2] [3]	707	304	18,912	745	324	20,068
Grand total	4,954	2,897	114,100	5,201	3,045	120,284

[1] Derived from reported value of "Sold or used."

[2] Figures for refined muriate and manure salts are included with potassium sulfate and potassium-magnesium sulfate to avoid disclosing individual company confidential data.

[3] Includes sulfate manufactured from captive production of muriate.

Lithium Corp. of America was attempting to acquire permission from the Utah State Land Board to extract minerals from Great Salt Lake. The company indicated plans to spend $30 million to produce potash and sodium sulfate provided it could obtain rights also to extract magnesium compounds, claiming that the venture could not be economical without recovery of magnesium. Hogle-Kearns Co. (H.–K.) of Salt Lake City obtained exclusive magnesium extraction rights from the State in 1961 and sublet an 80 percent interest to National Lead Co. The contract was to expire in 1969. Several companies continued active in exploring the geothermal brine deposit about a mile underground near the Salton Sea, Calif., but no plans were announced for commercial operations. Shell Development Co., Earth Energy Co., and Western Geothermal, Inc., completed drilling several wells. In addition, American Cyanamid Co. was considering a joint venture with one of the active firms. Hot brine from the wells drilled in to this deposit was stated to contain up to 4.5 percent potassium chloride in addition to several other inorganic salts.

Arkansas-Louisiana Co. joined the ranks of other major firms in prospecting for potash in an area about 35 miles wide and 55 miles long between Holbrook and St. Johns, Ariz. Potash was first discovered in the area early in 1963, and since then several major companies, including Duval Corp., U.S. Borax & Chemical Corp., and Kern County Land Co. have been exploring the deposits. Most of the prospecting permits are on State land and land owned by Arizona-New Mexico Land Co.

Texas Gulf Sulphur Co. (T.G.S.) took over the custody and control of its potash mine at Cane Creek, Utah. Harrison International, Inc., had been the contracting firm responsible for sinking the shaft to the ore body and for initial mine development. T.G.S. completed the development and began hoisting potash in December.

Duval Corp. completed sinking two new shafts and began mining langbeinite ore at its newly developed Nash Draw mine, about 22 miles east of Carlsbad, N. Mex. Also a new plant for processing the langbeinite was completed and put into operation to produce sulfate of potash-magnesia and potassium sulfate. The new plant was designed to produce about 50,000 tons of each of the two products annually. Before the new operation of Duval, International Minerals & Chemical Corp. was the only producer of langbeinite, a potassium-magnesium sulfate mineral. Duval Corp. acquired Ashcraft-Wilkinson Co. of Atlanta, Ga., as a subsidiary. The two companies had been closely associated since 1928 with Ashcraft-

TABLE 3.—Production and sales of potassium salts in New Mexico

(Thousand short tons and thousand dollars)

Year	Crude salts[1]		Marketable potassium salts					
	Mine production		Production			Sales		
	Gross weight	K_2O equivalent	Gross weight	K_2O equivalent	Value[2]	Gross weight	K_2O equivalent	Value
1955–59 (average)	12,389	2,358	3,439	2,029	$73,476	3,445	2,033	$73,551
1960	15,071	2,841	4,138	2,440	82,645	4,092	2,412	81,653
1961	15,653	2,934	4,281	2,523	96,380	3,882	2,281	87,415
1962	14,115	2,619	3,758	2,208	85,124	4,206	2,476	95,851
1963	16,414	3,083	[r] 4,504	[r] 2,643	[r] 100,458	[r] 4,213	[r] 2,484	[r] 94,925
1964	17,356	3,122	4,585	2,675	104,866	4,815	2,814	110,772

[r] Revised.

[1] Sylvite and langbeinite.

[2] Derived from reported value of "Sold or used."

Wilkinson acting as exclusive sales agent for the Duval sulfur and potash products.

In October Potash Co. of America stockholders approved the sale of the company to Esso Chemical Co., a subsidiary of Standard Oil Co. of New Jersey, for approximately $75 million in Standard Oil Co. stocks. The Department of Justice immediately filed an antitrust suit to block the transaction, claiming that the merger would substantially lessen competition in violation of the Clayton Act. The Federal district court in Newark, N.J., issued a temporary restraining order on October 23 barring the sale. Trial was tentatively set for January 25, 1965, to hear the charges.

Southwest Potash Corp., a division of American Metal Climax, Inc., announced plans for a 17-percent increase in output capacity of its potash operations near Carlsbad, N. Mex.

CONSUMPTION AND USES

Heavy demand for fertilizers in the United States was reflected by an increase of 10 percent in apparent consumption of potassium salts. Deliveries of potash for agricultural use in the United States and Puerto Rico reached nearly 3 million tons K_2O equivalent, a 10 percent gain over that of 1963. Also, a 10 percent increase in deliveries of nonagricultural potash was recorded.

Leading States in quantities delivered for agricultural use remained unchanged from the preceding year and were as follows in decreasing order: Illinois, Indiana, Ohio, Georgia, and Florida. Deliveries and consumption do not necessarily correspond because much of the potash delivered is used in mixed fertilizers and resold.

STOCKS

Stocks of potassium salts held by producers were decreased by 32 percent due to heavy demand, both domestic and foreign. Yearend stocks on hand included material sold for delivery during the 1965 spring planting season.

PRICES

Bulk prices on muriate of potash for the 1964–65 fertilizer year were 1, 2, and 3 cents per unit of K_2O, depending on the delivery date, higher than those for the same periods in 1963–64: 1 cent for July–August, 2 cents for September–October, and 3 cents for the remainder of the fertilizer year. One unit of K_2O is defined as equal to 1 short ton of material containing 1 percent K_2O equivalent, or 20 pounds. Thus, muriate of potash, 60 percent K_2O equivalent, represents 60 units of K_2O.

TABLE 4.—Deliveries of potash salts in 1964, by States of destination

(Short tons K_2O equivalent)

State	Agricultural potash	Chemical potash	State	Agricultural potash	Chemical potash
Alabama	96,166	24,307	Nebraska	8,264	101
Alaska	-----	-----	Nevada	-----	980
Arizona	910	133	New Hampshire	96	40
Arkansas	66,160	407	New Jersey	34,034	2,384
California	30,030	9,188	New Mexico	297	349
Colorado	2,360	1	New York	53,505	70,154
Connecticut	3,889	213	North Carolina	112,820	336
Delaware	10,027	639	North Dakota	4,633	-----
District of Columbia	550	-----	Ohio	201,612	6,104
Florida	179,566	1,563	Oklahoma	14,942	216
Georgia	181,129	971	Oregon	7,974	595
Hawaii	23,240	-----	Pennsylvania	43,324	3,328
Idaho	1,592	-----	Rhode Island	1,841	350
Illinois	343,638	23,477	South Carolina	78,145	-----
Indiana	251,833	3,209	South Dakota	1,625	-----
Iowa	139,678	196	Tennessee	95,201	38
Kansas	15,312	919	Texas	120,999	6,531
Kentucky	71,236	8,639	Utah	255	167
Louisiana	30,210	695	Vermont	4,056	-----
Maine	12,723	47	Virginia	119,842	574
Maryland	73,719	1,595	Washington	13,237	1,030
Massachusetts	14,570	205	West Virginia	1,801	12,304
Michigan	89,484	1,040	Wisconsin	108,762	100
Minnesota	101,678	-----	Wyoming	123	-----
Mississippi	78,032	-----	Unknown	7,454	-----
Missouri	101,239	1,745			
Montana	248	-----	Total	2,954,061	184,870

Source: American Potash Institute, Inc.

TABLE 5.—Stocks of potassium salts in the United States

(Thousand short tons)

Year	Number of producers	Stocks, Dec. 31	
		Gross weight	K_2O equivalent
1955–59 (average)	11	680	404
1960	11	521	311
1961	11	927	558
1962	11	475	286
1963	10	[r] 762	[r] 478
1964	10	519	295

[r] Revised.

Pricelists were published by producers for shipments during the months indicated against contracts made before July 1, 1964. The price was increased 2 cents per unit by some producers on contracts made after June 30, 1964, while others increased the price 5 percent.

An additional \$5.50 per short ton was charged by most producers for muriate shipped in 100-pound bags.

All producers reserved the right to adjust prices to meet competition.

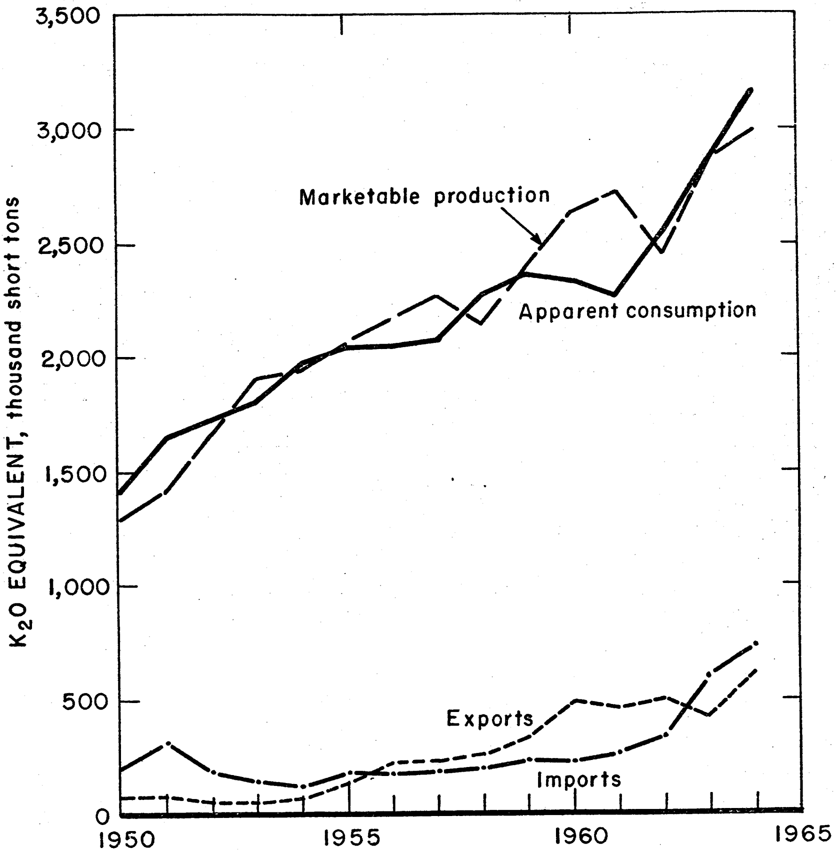

FIGURE 1.—Marketable production, apparent consumption, exports, and imports of potash, K_2O equivalent.

TABLE 6.—Bulk prices for New Mexico potash [1]

(Cents per unit K_2O)

Product	1964			1965	
	July-Aug.	Sept.-Oct.	Nov.-Dec.	Jan.	Feb.-June
Standard muriate, 60-percent, K_2O minimum	36	38	40	40	43
Coarse	37.5	39.5	41.5	41.5	44.5
Granular	40	42	44	44	47
Standard sulfate of potash, 50 percent, K_2O minimum [2]	70	73	76	76	79
Manure salts	17.65	17.65	17.65	17.65	17.65

[1] Quoted by producers, f.o.b. Carlsbad, in minimum 40-ton carlots.
[2] Coarse and granular when quoted: 3 cents and 5 cents higher, respectively.

TABLE 7.—Bulk prices for California potash [1]

(Cents per unit K_2O)

Product	1964			1965	
	July-Aug.	Sept.-Oct.	Nov.-Dec.	Jan.	Feb.-June
Standard	45	46	47	47	49.5
Coarse	46.5	47.5	48.5	48.5	51
Sulfate	81	83.5	86	86	89

[1] Quoted by American Potash & Chemical Corp. carlots, f.o.b. Trona, Calif.

FOREIGN TRADE

Imports.—Muriate of potash imports increased 31 percent to a record high, more than 1 million tons. Canada increased shipments into the United States by nearly 49 percent, supplying 72 percent of the total muriate imported. The tonnage of crude potassium sulfate imported continued to decrease and was about 35 percent less than in 1963.

Exports.—More than 1 million tons of potash materials for fertilizers was shipped by domestic producers to foreign destinations, a record quantity representing an increase of 45 percent from 1963. Better than 40 percent of total exports went to Japan. Deliveries to Japan had been declining for 3 years, but shipments in 1964 were only 11 percent less than the record set in 1960.

TABLE 8.—U.S. imports for consumption of potash materials

Material	Approximate K_2O equivalent percent	1963				1964			
		Short tons	Approximate K_2O equivalent		Value	Short tons	Approximate K_2O equivalent		Value
			Short tons	Percent of total			Short tons	Percent of total	
Used chiefly as fertilizers:									
Muriate, chloride [1]	60	882,731	529,663	89.2	$22,559,966	1,159,702	695,545	94.3	$29,202,170
Potassium nitrate, crude	40	4,446	1,778	.3	228,239	3,163	1,265	.2	146,896
Potassium sodium nitrate mixtures, crude	14	38,080	5,331	.9	1,578,601	18,618	2,607	.3	782,601
Potassium sulfate, crude [1]	50	103,704	52,096	8.8	3,978,900	67,233	33,656	4.6	2,595,297
Other potash fertilizer materials	6	1,933	116	.0	54,921	204	12	.0	7,421
Total		1,030,894	588,984	99.2	28,400,627	1,248,920	733,085	99.4	32,734,385
Used chiefly in chemical industries:									
Bicarbonate	46	558	257	.8	60,645	113	52	.6	11,545
Bitartrate: Cream of tartar	25	1,253	313		548,616	1,453	363		620,164
Carbonate	61	323	197		41,292	272	166		35,233
Caustic	80	1,044	835		184,537	923	738		186,685
Chlorate and perchlorate	36	789	284		163,072	763	275		160,966
Cyanide	70	867	607		444,676	1,055	739		504,063
Ferricyanide	42	381	160		227,499	519	218		342,557
Ferrocyanide	44	700	308		244,517	836	368		304,424
Nitrate	[r]50	3,517	[r]1,759		425,738	2,766	1,383		326,009
Rochelle salts	22	291	64		113,996	252	55		96,292
All other	[r]31	759	[r]238		281,770	1,262	391		721,776
Total		10,482	[r]5,022	.8	2,736,358	10,214	4,748	.6	3,309,714
Grand total		1,041,376	[r]594,006	100.0	31,136,985	1,259,134	737,833	100.0	36,044,099

[r] Revised. [1] Values adjusted by Bureau of Mines. Source: Bureau of the Census and American Potash Institute, Inc.

TABLE 9.—U.S. imports for consumption of potash materials, by countries

(Short tons)

Year and country	Bitartrate, cream of tartar	Caustic, hydroxide	Chlorate and perchlorate	Cyanide	Muriate, chloride	Potassium nitrate, crude	Potassium sodium nitrate mixtures, crude	Potassium nitrate, saltpeter, refined	Potassium sulfate, crude	All others	Total	
											Quantity	Value [1]
1963:												
Belgium-Luxembourg		11		15				130		205	361	$152,663
Canada				42	563,344		662			733	564,781	13,030,628
Chile						3,858	36,696				40,554	1,670,994
France		29		115	176,479	181	45		46,262	1,730	224,841	7,602,353
Germany:												
East								240		88	328	70,508
West		812	11	406	110,671	396	677	1,895	34,711	803	150,382	5,241,963
Italy	775			81		11		891	18,270	88	20,116	1,295,428
Netherlands		4		5				12		967	988	303,229
Spain	200		193		32,237			332	4,351	77	37,390	1,253,697
Sweden		188	369								557	155,758
United Kingdom	250			186						208	644	246,233
Other countries	28		216	17				17	110	46	434	113,531
Total	1,253	1,044	789	867	882,731	4,446	38,080	3,517	103,704	4,945	1,041,376	31,136,985
1964:												
Belgium-Luxembourg		5				10		44		287	346	179,786
Canada				35	837,357	51	13		202	3	837,661	9,394,361
Chile						1,500	13,485				14,985	613,002
France	80	48		76	170,580	82			33,525	226	204,617	7,081,810
Germany:												
East			15					320		64	399	97,627
West		594	11	485	116,787	1,498		1,537	18,960	1,153	141,025	5,048,989
Italy	664			66			5,120	99	14,546	78	20,573	1,190,933
Netherlands		13				22		44		1,093	1,172	374,650
Spain	389		28		34,978			573		75	36,043	1,200,897
Sweden		257	418								675	188,067
United Kingdom	1			189						233	423	151,441
Other countries	319	6	291	204				149		246	1,215	522,536
Total	1,453	923	763	1,055	1,159,702	3,163	18,618	2,766	67,233	3,458	1,259,134	36,044,099

[1] Adjusted by Bureau of Mines except Canada in 1963-64 and Italy and Israel in 1963.

Source: Bureau of the Census and American Potash Institute, Inc.

TABLE 10.—U.S. exports of potash materials, by countries

Destination	Fertilizer				Chemical			
	1963		1964		1963		1964	
	Short tons	Value	Short tons	Value	Short tons	Value	Short tons	Value
North America:								
Canada	51,698	$2,179,073	64,467	$2,209,462	6,743	$1,335,108	7,566	$1,483,869
Costa Rica	14,013	403,681	11,573	353,897	7	2,058	4	1,240
Dominican Republic	1,750	62,563	4,200	166,329	12	3,516	17	2,474
Mexico	26,459	707,322	37,214	987,250	1,093	233,066	1,209	224,646
Netherlands Antilles	10	372	15,292	415,291	--------	----------	46	14,135
Other	1,888	82,778	17,459	671,068	74	23,622	121	34,630
Total	95,818	3,435,789	150,205	4,803,297	7,929	1,597,370	8,963	1,760,994
South America:								
Argentina	1,753	48,120	441	15,498	193	73,080	460	129,840
Brazil	23,425	741,055	28,549	1,042,077	903	204,249	517	135,131
Chile	8,105	193,404	16,371	575,234	211	36,400	75	21,444
Colombia	15,195	498,875	40,143	1,230,558	114	31,135	1,201	73,094
Peru	116	4,646	893	37,772	47	13,283	61	23,195
Venezuela	1,109	38,000	6,674	269,615	207	55,369	248	63,640
Other	24	924	2,513	93,372	14	4,301	158	29,876
Total	49,727	1,525,024	95,584	3,264,126	1,689	417,817	2,720	476,220
Europe:								
Belgium-Luxembourg	--------	----------	1,092	32,175	139	41,348	798	199,689
Germany, West	--------	----------	3,145	28,336	730	248,046	2,352	740,392
Ireland	12,768	356,237	5,544	145,084	103	27,803	--------	----------
Italy	--------	----------	2,564	75,767	483	105,150	1,261	297,316
Netherlands	--------	----------	771	25,154	298	129,459	620	199,979
Sweden	2,205	58,267	13,779	434,850	873	58,237	457	40,790
United Kingdom	735	35,862	727	35,327	846	220,767	676	194,141
Other	--------	----------	7,089	211,690	331	132,630	1,242	347,276
Total	15,708	450,366	34,711	988,383	3,803	963,440	7,406	2,019,583
Asia:								
India	--------	----------	--------	----------	42	6,320	299	75,856
Japan	351,500	11,108,771	434,976	13,622,506	35	23,002	918	203,754
Korea, South	74,725	2,209,107	55,358	1,797,031	10	3,035	4	2,068
Pakistan	--------	----------	--------	----------	227	53,640	299	67,180
Philippines	12,261	404,199	7,616	239,041	151	34,163	73	30,835
Taiwan	15,792	427,475	11,574	410,739	94	16,990	23	14,721
Vietnam	3,735	136,719	1,709	64,128	75	19,689	41	9,589
Other	183	7,756	--------	----------	164	39,538	165	43,749
Total	458,196	14,294,027	511,233	16,133,445	798	196,377	1,822	447,752
Africa:								
South Africa, Republic of	41,806	1,164,375	51,009	1,446,803	81	19,339	112	32,968
Other	851	37,488	556	21,953	21	5,093	290	89,124
Total	42,657	1,201,863	51,565	1,468,756	102	24,432	402	122,092
Oceania:								
Australia	16,062	446,079	68,353	1,948,888	372	112,446	545	152,137
New Zealand	28,871	848,738	114,795	3,955,605	10	5,250	175	44,818
Total	44,933	1,294,817	183,148	5,904,493	382	117,696	720	196,955
Grand total	707,039	22,201,886	1,026,446	32,562,500	14,703	3,317,132	22,033	5,023,596

Source: Bureau of the Census.

WORLD REVIEW

Canada.—Exploration and development of the huge potash area of Saskatchewan, extending into Manitoba ,continued with increasing activity. By the end of 1964 about 4 million acres of potash rights were held under permit and lease by 24 companies. Increasing world demand; unusual richness and vastness of the Canadian deposits; success in underground mining by International Minerals & Chemical Corp. (Canada), Ltd.; and the more recent success in solution mining by Kalium Chemicals, Ltd., were the chief factors in promoting this flurry of activity. It has been estimated that by 1970 production capacity of Canadian potash will total 9.6 million tons of product per year.[3]

TABLE 11.—World production of marketable potash by countries [1]

(Short tons, K_2O equivalent)

Country	1955-59 (average)	1960	1961	1962	1963	1964
North America:						
Canada	[2] 46,500	----------	----------	[e] 150,000	626,860	862,440
United States	2,207,140	2,638,574	2,732,602	2,452,921	2,864,037	2,897,000
South America: Chile (nitrate)	10,879	[e] 16,500	15,504	19,541	[e] 20,500	[e] 14,000
Europe:						
France	1,511,781	1,688,635	1,884,791	1,897,958	2,112,026	1,990,772
Germany:						
East	1,658,977	1,836,000	1,846,000	1,931,000	2,034,000	[e] 2,135,000
West	1,893,145	2,181,206	2,253,122	2,138,637	2,147,300	[e] 2,430,000
Italy	[3] 10,438	54,338	149,187	170,142	207,565	[e] 239,000
Spain	257,986	291,356	289,037	259,156	286,876	322,551
U.S.S.R. [e]	1,030,300	1,212,500	1,455,000	1,650,000	1,700,000	1,750,000
Asia: Israel [4]	47,100	91,000	93,600	100,200	124,560	330,700
Africa: Eritrea	[5] 450	----------	----------	----------	----------	----------
World total [e] [1]	8,700,000	10,000,000	10,700,000	10,800,000	12,100,000	13,000,000

[e] Estimate.

[1] Table incorporates revisions. Data do not add exactly to totals shown because of rounding where estimated figures are included in the detail.

[2] Data for year 1959.

[3] Average annual production for years 1958-59.

[4] Year ended Mar. 31, of year following that stated.

[5] Data for year 1958.

Alwinsal Potash of Canada, Ltd., a company controlled by French and German mining interests, awarded contracts for sinking a 3,400-foot shaft and constructing a refinery near Lanigan, Saskatchewan, 70 miles east of Saskatoon. The refinery was designed for an initial capacity of 1 million tons of product annually and was scheduled for operation late in 1968.[4]

Continental Potash Corp. was reported to have entered into an agreement with Gulf Sulphur Corp. under which the latter would take over 76,000 acres of potash properties in Saskatchewan. The properties were to be transferred to Gulf Sulphur Corp., with Continental Potash Corp. retaining 20 percent of profit from the properties before income taxes. The agreement required Gulf Sulphur Corp. to invest about $20 million to deepen the existing mine shaft to 3,400 feet and to construct plant facilities for processing about 4,000 tons of ore a day. However, Gulf Sulphur Corp. was allowed to make geological engineering and feasibility studies before mine and plant development.

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[3] Bartley, C. M. Potash. Preliminary Min. Inf. Bull. MR 79, Min. Res. Division, Dept. Mines and Tech. Surveys, Ottawa, Canada, February 1965, pp. 56-59.

[4] Metal Mining and Processing. Alwinsal Contracts $50 Million Potash Project. V. 1, No. 10, October 1964, p. 18.

International Minerals & Chemical Corp. (Canada), Ltd., began a 33-percent expansion of its mine and refinery to increase production capacity to 1.6 million tons of product annually by the end of 1964. The sinking of a second shaft, which would raise annual product output to 4 million tons, was started 6 miles from the present plant and was scheduled for completion in fiscal 1968.

Kalium Chemicals, Ltd., began shipping potash from its plant near Regina, Saskatchewan on September 29. More than 7,000 tons of standard grade 62-plus percent muriate of potash was shipped by train to 19 States in the United States and 6 Canadian Provinces.

Consolidated Morrison Explorations, Ltd., completed another test hole into its deposit east of Saskatoon. The test showed the total reserves to be more than 600 million tons of which 400 million tons averages 29.77 percent K_2O.[5] It was announced later in the year, however, that the company approved the sale of its potash properties to Noranda Mines, Ltd., for about $7.2 million. Noranda Mines, Ltd., had previously acquired an option on the potash property held by Tombill Mines, Ltd.

Potash Co. of America delayed production from its potash mine east of Saskatoon. Some changes were made in the plant incorporating the most modern equipment. A new hoist was being installed at the mine, and a new waterline was under construction to insure an adequate water supply to the plant. Negotiations were underway for the purchase of all the company assets by a subsidiary of Standard Oil Co. of New Jersey.[6]

A third drill hole was completed on the potash property held by Prairie Potash Mines. A 12-foot-thick bed of high-grade potash was located 3,116 feet below the surface. The company holds a potash permit on an area covering about 25,000 acres near St. Lazarre, Manitoba.[7]

U.S. Borax & Chemical Corp. with Homestake Mining Co. as a partner, began construction of a $60 million potash mine and mill at Allan, Saskatchewan, 35 miles southeast of Saskatoon. Two shafts were being sunk simultaneously 500 feet apart at the project site 3 miles north of Allan. The shaft sinking was to continue without interruption until completion in early 1968. The refinery, one of the largest in the potash industry, was expected to have an initial capacity of about 1.5 million tons per year.[8] Later in the year, Swift Agricultural Chemical Corp. joined as a third partner in the venture.[9]

Congo (Brazzaville), Republic of.—Plans were made by Compagne des Potasses du Congo to bring into production a high-grade potash deposit at Hollé, 25 miles from the port of Pointe-Noire.

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[5] Northern Miner (Toronto, Canada). Drill Hole Expands Reserves of Potash at Cons. Morrison. V. 50, No. 20, Aug. 6, 1964, pp. 1, 11

[6] Northern Miner (Toronto, Canada). Production Delayed at Potash Company Until Next Year. V. 50, No. 26, Sept. 17, 1964, pp. 13, 18.

[7] Northern Miner (Toronto, Canada). Complete Third Hole at Prairie Potash. V. 50, No. 28, Oct. 1, 1964, p. 3.

[8] Western Miner (Vancouver, Canada). New $60 Million Potash Mine for Saskatchewan. V. 37, No. 9, Sept. 1964, p. 43.

[9] Chemical Week. V. 95, No. 14, Oct. 3, 1964, pp. 27-28.

American Potash & Chemical Corp. held a 42.5 percent interest in the company and the Congolese Government, a 15 percent interest. The remaining 42.5 percent was held by French interests.[10]

Ethiopia.—International Minerals & Chemical Corp. sent mining experts to the Danakil Depression to assist Ralph M. Parsons Co. in developing an underground potash mine.[11] Ralph M. Parsons Co. has been working on this development for about 2 years.

TABLE 12.—France: Exports of potash materials [1] by countries [2]

(Short tons)

Destination	1962	1963
North America:		
Canada	29,201	14,009
Martinique	6,592	5,251
United States	179,466	157,842
South America:		
Brazil	27,776	30,993
Chile	4,382	1,342
Colombia	4,409	3,105
Venezuela	2,792	-----
Europe:		
Austria	30,081	22,537
Belgium-Luxembourg	149,690	267,043
Denmark	41,454	34,589
Finland	1,666	6,061
Germany, West	39,090	43,018
Greece	3,790	2,258
Ireland	67,718	66,686
Italy	53,723	50,425
Netherlands	77,632	93,021
Norway	9,377	11,207
Sweden	33,630	37,739
Switzerland	87,010	83,469
United Kingdom	252,734	221,877
Asia:		
Ceylon	37,541	45,477
India	11,198	2,549
Indonesia	1,615	2,304
Japan	122,223	138,471
Malaysia	4,016	3,061
Philippines	1,901	7,372
Taiwan	11,170	293
Africa:		
Algeria	1,412	9,930
Ivory Coast	5,964	5,175
Malawi, Southern Rhodesia, and Zambia	8,588	10,030
Morocco: Southern Zone	6,236	4,403
Senegal	2,381	1,102
South Africa, Republic of	26,171	33,460
Tanzania	5,081	5,561
Tunisia	4,162	3,904
Oceania:		
Australia	8,386	18,317
New Zealand	26,767	808
Other countries	29,086	23,051
Total	1,416,111	1,467,740

[1] Figures include salts, carbonate, chloride, and nitrate of potash.
[2] This table incorporates some revisions.

Israel.—The Dead Sea Works celebrated its 30th anniversary with the opening of a new potash processing plant. The old plant, having a capacity of 200,000 tons per year, was to continue operating; the new plant was expected to produce an additional 400,000 tons per year when in full operation. Most of the output from the new plant will be exported.[12] A large potassium nitrate chemical plant was scheduled for construction at Ashdod. The plant, when in operation, will use potash supplied by the Dead Sea Works at Sdom.[13]

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[10] World Mining. American Potash-French-Congo Group To Develop Potash Mine. V. 17, No. 11, October 1964, p. 81.
[11] World Mining. V. 17, No. 5, May 1964, p. 25.

Libya.—Cabbin Exploration Corp. (a U.S. firm) acquired an option on a concession to exploit deposits of magnesium and potassium in the Marada region. The deposits are 80 kilometers from the coast, and it was stated that potash probably would be produced first for domestic agricultural use.[14]

TABLE 13.—West Germany: Exports of potash materials [1] by countries

(Short tons)

Destination	1963	1964
North America:		
Canada	9,593	7,850
Cuba	-----	3,737
Jamaica	3,621	6,949
United States	199,175	140,063
South America:		
Brazil	44,030	23,058
Chile	3,056	6,895
Colombia	10,391	4,960
Uruguay	1,754	1,704
Europe:		
Austria	-----	62,982
Belgium-Luxembourg	126,610	197,165
Czechoslovakia	4,433	882
Denmark	148,911	181,431
Finland	17,214	25,916
France	33,119	8,767
Germany, East	71,325	-----
Greece	8,392	10,485
Hungary	55	16,634
Ireland	50,589	48,178
Italy	30,562	37,269
Netherlands	187,263	210,998
Norway	11,296	19,390
Poland	-----	35,249
Sweden	53,395	55,401
Switzerland	36,957	28,658
United Kingdom	225,686	216,263
Yugoslavia	22,047	22,046
Asia:		
Ceylon	13,029	6,750
India	13,907	15,344
Korea, North	-----	11,023
Japan	106,597	126,055
Malaysia	11,806	10,104
Philippines	6,107	12,897
Taiwan	38,917	11,464
Africa:		
Malawi, Southern Rhodesia, and Zambia	15,350	22,095
Morocco	2,841	120
South Africa, Republic of	44,266	51,386
Oceania:		
Australia	52,926	35,342
New Zealand	45,554	14,927
Other countries	[r] 37,096	36,855
Total	1,687,870	1,727,292

[r] Revised.
[1] Data include crude salts, chloride, sulfate, magnesium sulfate, and beet ash.

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[12] European Chemical News (London). Dead Sea Works' New Potash Plant Opened. V. 6, No. 151, Dec. 4, 1964, p. 10.

[13] Fertilizer & Feeding Stuffs Journal (London). Nitrate of Potash in Israel. V. 61, No. 11, Nov. 25, 1964, p. 391.

[14] Chemical Trade Journal and Chemical Engineer (London). V. 154, No. 4001, Feb. 14, 1964, p. 229.

TABLE 14.—Spain: Exports of potash materials by countries [1]

(Short tons)

Destination	1963	1964
North America:		
Cuba	-----	16,535
United States	39,129	35,274
South America: Chile	16,535	8,818
Europe:		
Belgium-Luxembourg	28,765	22,579
Denmark	6,118	3,775
Finland	-----	2,001
Ireland	-----	22,811
Italy	25,179	50,546
Netherlands	15,695	24,229
Norway	73,883	69,600
Portugal	22,694	25,033
Sweden	-----	6,311
United Kingdom	54,547	48,728
Africa:		
Algeria	1,234	3,549
Morocco	-----	1,979
Other countries	220	-----
Total	283,999	341,768

[1] This table incorporates some revisions.

TECHNOLOGY

The successful recovery of potash in Saskatchewan, Canada, by Kalium Chemicals, Ltd., using solution mining techniques was a major breakthrough in potash mining technology. Although the success of the operation was highly publicized, details of the process used were not released by the company. An article was published, however, describing the techniques thought to be used, based on a Canadian patent held by Pittsburgh Plate Glass Co.[15]

Canadian patent, 683,994, issued to Pittsburgh Plate Glass Co., involved the use of a hydrocarbon or other fluid that is water-immiscible, lighter than water, and not an ore solvent, to blanket the roof of an underground water filled cavity, thus causing it to grow laterally. This was thought to be involved also in the Kalium Chemicals, Ltd., technique for mining potash in Saskatchewan.[16]

An article on the potash deposit at Starobin, south of Monok, U.S.S.R. was published.[17] The nature of the deposit, claimed to be the largest in Europe, and several methods investigated for benefication of potash ore were briefly discussed.

U.S. Borax & Chemical Corp. applied special mining techniques in its Carlsbad, N. Mex. operation to recover potash from pillars previously considered lost due to back falls. An economical and safe system was developed which recovers about 55 percent of the pillars, thereby extending the life of the entire operation by approximately 1 year.[18]

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[15] Phosphorous and Potassium. Kalium Chemical Co. to Start Mining Potash Shortly. No. 10, April 1964, pp. 35–37.

[16] Chemical Engineering. Hydrocarbon "Blanket" Is Key to Solution Mining of Canadian Potash. V. 71, No. 10, May 11, 1964, p. 81.

[17] Phosphorous and Potassium. Beneficiation of Potash at Starobin. No. 11, June 1964, pp. 30–31.

[18] Wright, J. S., and J. C. Horne. Special Pillar Recovery Technique. Min. Cong. J., v. 50, No. 9, September 1964, pp. 74–77.

In the Carlsbad potash basin, Kermac Potash Co. completed its shaft-sinking operation. The operation was unusual in that the entire shaft, 1,650 feet deep, was sunk using a large rotary drill. A 10-foot, 4-inch-diameter bit was used to drill the first 935 feet, after which an 8-foot, 8-inch ID steel liner was fixed into place. The lower portion of the shaft was drilled using an 8-foot, 6-inch-diameter bit. This operation was stated to be one of the largest and deepest rotary-drilled mine shafts in the world.[19]

A study was made of a process for extracting potassium from adularia shales such as those of the Northwest Highlands of Scotland. The shale was fused with limestone at 1,500° C., quenched in water to form a glass, and leached with acid after grinding. When a hot nitric acid leach was used, 97.7 percent K_2O was extracted. It was suggested that commercial grades of silica and alumina as well as potassium nitrate for fertilizer could be produced. Results of the tests indicated that further study was warranted.[20]

Engineering of a unique pipeline for tailing disposal at the new International Minerals & Chemical Corp., Canada, Ltd., potash processing plant at Esterhazy, Saskatchewan, was described. Because of severe winters, temperatures of minus 30° F. being common, free drainage was necessary to prevent the waste slurry from freezing in the line in the event of a power failure. The pipeline system installed required only regular normal preventative maintenance and successfully discharged tailings at a point 1,575 feet from the pumps in the winter and distributed tailings over an area up to 5,000 feet from the pumps in the summer.[21]

Solar evaporation of the five component system consisting of chloride, sulfate, sodium, potassium, and magnesium ions in water was discussed.[22] The system corresponds to the brines found at Wendover, Utah, the Great Salt Lake, and sea water bitterns. The Bonneville operation at Wendover was discussed in detail. It was shown that because of the larger quantities of sulfate ions present in the Great Salt Lake and in sea water bitterns, potash cannot be recovered from these sources by the same procedure used at Bonneville.

A variety of methods proposed for recovery of potassium from sea salt were discussed briefly and referenced extensively.[23]

Transporting potash by pipeline from mine to major markets was in the serious planning stage. Prairie Commodities Pipeline, Ltd., (P.C.P.) was stated to be ready to proceed with plans for a $55 million line from the Saskatchewan potash fields to major midwestern U.S. markets by way of Chicago.[24] P.C.P. claimed that it could move potash from Saskatoon and Regina to Chicago for $6 per ton using a water slurry.

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[19] Phosphorous and Potassium. Drilling and Shaft-sinking at Kermac's Carlsbad Potash Mine. No. 9, February 1964, pp. 31–32.

[20] Everest, D. A., E. Napier, and R. A. Wells. Extraction of Potassium From Adularia Shale. Chem. and Ind. (London), No. 40, Oct. 3, 1964, pp. 1684–1685.

[21] Mitchell, Jack, and Robert Beach. Unique IMC Tailing Line Solves Freezing Problem. Eng. and Min. J., v. 165, No. 8, August 1964, pp. 94–96.

[22] Hadzeriga, Pablo. Some Aspects of the Physical Chemistry of Potash Recovery by Solar Evaporation of Brines. Soc. of Min. Eng., Trans., v. 229, No. 2, June 1964, pp. 169–174.

[23] Tallmadge, J. A., J. B. Butt, and Herman J. Colomon. Minerals From Sea Salt. Ind. and Eng. Chem., v. 56, No. 7, July 1964, pp. 56, 57.

[24] Chemical Week. Pushing Potash Pipeline. V. 95, No. 23, Dec. 5, 1964, pp. 71–74.

Pumice

By Timothy C. May[1]

⁂

AS A RESULT of greater use of pumice for road construction, a low value item, there was a 6-percent increase in production in 1964 while total value dropped slightly. Among the States, Hawaii increased output of pumice and pumiceous materials by 33 percent while production in Idaho was 63 percent lower.

DOMESTIC PRODUCTION

Production was reported from 16 States, 1 more than in 1963. Output came from 119 companies, individuals, or Government agencies at 139 properties, compared with 97 different producing entities at 103 separate operations in 1963.

Arizona, with nine active pumice mines and 32 percent of the total production, continued for the fifth successive year to be the leading producer. Oregon was second with 29 mines and 20 percent of production; California, with 16 percent from 43 mines; Hawaii, 13 percent from 21 mines; New Mexico, 9 percent from 10 mines; the remaining portion came from 11 States with 27 mines.

TABLE 1.—Pumice sold or used by producers in the United States

(Thousand short tons and thousand dollars)

Year	Pumice and pumicite		Volcanic cinder		Total	
	Quantity	Value	Quantity	Value	Quantity	Value
1955–59 (average)	898	$3,023	974	$1,756	1,872	$4,779
1960	601	2,767	1,609	2,802	2,210	5,569
1961	936	4,203	1,527	2,596	2,463	6,799
1962	533	3,206	1,738	3,095	2,271	6,301
1963	1,050	3,321	1,568	3,257	2,618	6,578
1964	1,165	4,094	1,611	2,349	2,776	6,443

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[1] Commodity specialist, Division of Minerals.

TABLE 2.—Pumice[1] sold or used by producers in the United States

(Thousand short tons and thousand dollars)

State	1963		1964	
	Quantity	Value	Quantity	Value
Arizona	800	$1,877	880	$1,635
California	460	2,017	443	1,937
Colorado	60	87	61	114
Hawaii	274	469	365	603
Idaho	161	275	59	100
New Mexico	322	850	260	760
Oregon	422	664	566	909
Utah	28	46	(2)	(2)
Other States[3]	91	293	142	385
Total	2,618	6,578	2,776	6,443

[1] Includes pumicite and volcanic cinder.
[2] Included with "Other States" to avoid disclosing individual company confidential data.
[3] Kansas, Montana, Nebraska, Nevada, Oklahoma, Texas, Washington, Wyoming, and States indicated by footnote 1.

TABLE 3.—Pumice[1] sold or used by producers in the United States, by uses

(Thousand short tons and thousand dollars)

Use	1963		1964	
	Quantity	Value	Quantity	Value
Abrasive: Cleaning and scouring compounds	25	$773	10	$689
Concrete admixture and concrete aggregates	894	2,972	925	2,946
Railroad ballast	609	592	629	543
Road construction[2]	846	1,123	1,008	1,260
Other uses[3]	244	1,118	204	1,005
Total	2,618	6,578	2,776	6,443

[1] Includes pumicite and volcanic cinder.
[2] Includes surfacing, ice control, and maintenance.
[3] Includes abrasive uses (miscellaneous), absorbents, fillers, filtration, insecticides, landscaping, paint, roofing aggregate, soil conditioners, and miscellaneous uses.

CONSUMPTION AND USES

In 1964, 36 percent of all pumice consumed was used in road construction, 33 percent as aggregate and admixtures in concrete, and 23 percent as railroad ballast. Smaller quantities of pumice, pumicite, volcanic cinders, and scoria were used in insecticides, absorbents, fillers, paint, soil conditioners, roofing aggregate, and miscellaneous applications.

PRICES

Nominal price quotations covering domestic and imported prepared pumice were carried regularly in trade publications. The quotations reported in Oil, Paint and Drug Reporter on domestic and imported pumice remained the same as in 1963. The E&MJ Metal and Mineral Markets quoted prices of pumice, f.o.b. New York or Chicago, in barrels, powdered, $0.0350 to $0.0600 per pound, and lump, $0.0600 to $0.0800 per pound.

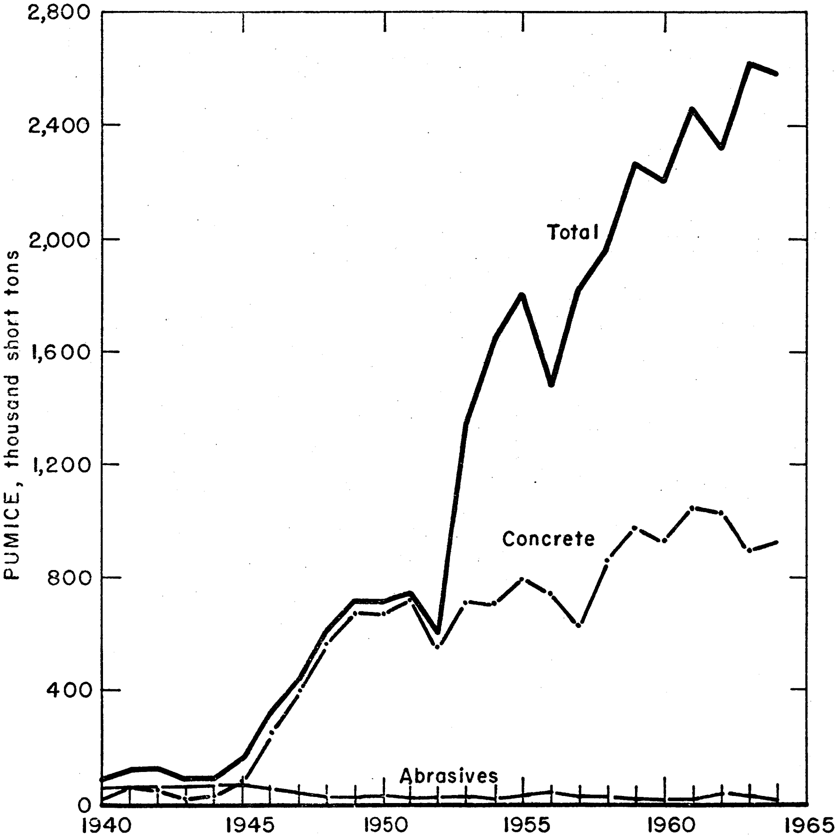

FIGURE 1.—Trends in pumice by uses.

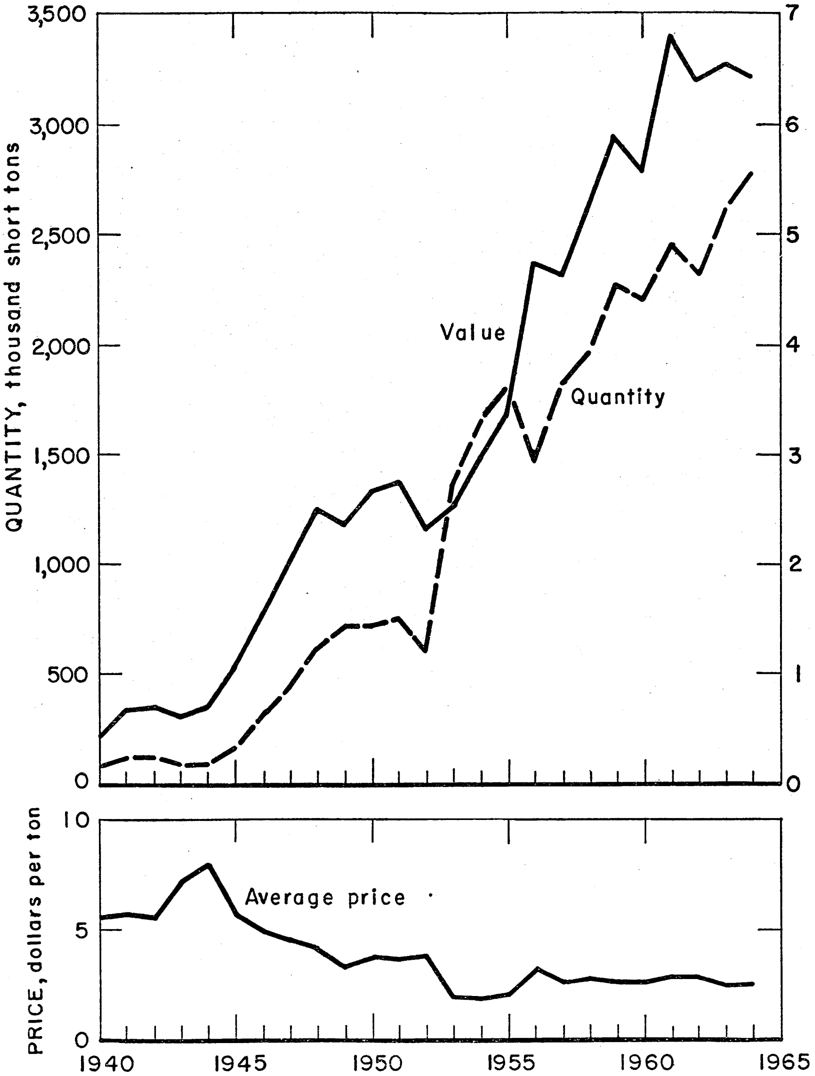

FIGURE 2.—Total value, quantity, and average price per ton of pumice.

FOREIGN TRADE

TABLE 4.—U.S. imports for consumption of pumice, by countries

Country	Crude or unmanufactured				Wholly or partly manufactured				Pumice[1]				Manufactured n.s.p.f.	
	1963		1964		1963		1964		1963		1964		1963	1964
	Short tons	Value	Short tons	Value	Short tons	Value	Short tons	Value	Short tons	Value	Short tons	Value	Value	Value
Greece	-----	-----	-----	-----	-----	-----	-----	-----	52,881	$77,948	60,094	$128,759	-----	-----
Italy	7,576	$83,600	5,499	$64,844	3,555	$118,939	3,092	$105,444	93,907	178,231	28,007	100,429	[r] $767	$6,229
Other	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	13,251	22,221	[r] 46,331	14,110
Total	7,576	83,600	5,499	64,844	3,555	118,939	3,092	105,444	146,788	256,179	101,352	251,409	47,098	20,339

[r] Revised.

[1] To be used in manufacturing concrete masonry products.

Source: Bureau of the Census.

WORLD REVIEW

Canada.—There were two operating pumice lightweight aggregate plants in Canada in 1963; Miron Company Ltd., Montreal, Quebec; and Ocean Cement Ltd. (formerly Evans, Coleman & Evans, Ltd.), Vancouver, British Columbia. The value of pumice used as lightweight aggregate was 36 percent lower than 1962. All the pumice used was imported from the United States and was used as aggregate in concrete blocks.[2]

TABLE 5.—World production of pumice by countries [1] [2]

(Short tons)

Country [1]	1955–59 (average)	1960	1961	1962	1963	1964 [p]
Argentina [3]	25,548	16,573	32,321	12,585	7,790	5,712
Austria: Trass	38,819	38,581	40,846	30,696	23,349	25,223
Cape Verde Islands: Pozzolan	[4] 10,033	7,094	7,361	7,503	13,035	[5] 13,035
France:						
Pumice	8,475	995	1,455	1,876	849	[5] 849
Pozzolan	424,716	475,484	485,724	521,751	601,488	638,899
Germany, West (marketable)	3,525,628	4,742,138	5,898,461	6,290,883	7,044,863	6,416,547
Greece:						
Pumice	64,059	88,185	77,162	87,938	[e] 88,000	[e] 88,000
Santorin earth	87,119	198,416	209,439	207,273	[e] 220,000	[e] 220,000
Iceland	[e] 13,900	[e] 9,000	[e] 9,000	[e] 7,200	13,779	11,023
Italy:						
Pumice	203,902	345,390	310,893	349,862	[e] 3,970,000	[e] 3,970,000
Pumicite	71,358	124,671	161,488	[e] 165,000		
Pozzolan	2,629,892	3,494.273	3,212,787	3,320,114		
Japan	[6] 121,250	(7)	(7)	(7)	(7)	(7)
Kenya	[8] 1,872	2,711	779	1,243	1,245	1,585
New Zealand	18,369	49,204	36,637	36,425	18,599	22,980
Spain: Canary Islands	892	1,614	1,585	1,918	1,685	[5] 1,685
United Arab Republic (Egypt)	1,219	3,307	4,335	2,276	9,614	23,779
United States (sold or used by producers):						
Pumice and pumicite	898,806	601,315	936,039	[9] 583.716	1,050,178	1,165,379
Volcanic cinder	973,754	1,609,050	1,526,546	1,737,587	1,567,825	1,611,093
World total (estimate) [1] [2]	9,120,000	11,900,000	13,100,000	13,500.000	14,800,000	14,340,000

[e] Estimate. [p] Preliminary.

[1] Pumice is also produced in Mexico and U.S.S.R., but data on production are not available; no estimates are included in total, but it is believed that U.S.S.R. produces a sizable quantity.

[2] This table incorporates some revisions. Data do not add exactly to totals shown because of rounding where estimated figures are included in the detail.

[3] Includes volcanic ash and cinders, and pozzolan.

[4] Data for year 1959 only.

[5] 1963 data.

[6] Data for year 1958 only.

[7] Data not available; estimate by author of chapter included in total.

[8] Average annual production 1956–59.

[9] Includes American Samoa.

TECHNOLOGY

New petrographic and chemical data indicate that the great Mount Mazama eruption of Crater Lake, Oregon, about 6,600 years ago was the source of most ash which has been called "Glacier Peak," and some of the ash called "Galata." Glacier Peak volcano in Washington was the source of an older ash deposit of the late glacial or early postglacial epoch.[3]

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[2] Wilson, H. S. Lightweight Aggregates (1963 Preliminary). Canada Dept. Mines and Tech. Surveys (Ottawa, Canada), May 1964, pp. 1–6.

[3] Powers, H. A., and R. E. Wilcox. Volcanic Ash from Mount Mazama (Crater Lake) and from Glacier Peak. Science, v. 144, No. 3634, September 1964, pp. 1334–1336.

Three summit and one flank eruptive phases of the 1961 eruption of Kilauea Volcano are described. Composition of the pumice formed by the lava is included.[4]

Explosive submarine eruptions contributed large volumes of pumiceous dacitic debris to the Tokiwa Formation (Miogene) of South Fossa Magna, Japan. In the Tokiwa area, pyroclastic eruptions produced five main sequences of dacitic debris.[5]

A bulletin on Hawaiian volcanoes continues the systematic account of conditions at volcanoes begun in earlier reports. Observations made during 1955 are described in detail.[6]

Volcanic cinder from the recent eruptions of the volcano Irager in Costa Rica was used for the manufacture of cinder block.[7]

The use of pumice as a bonding material in the manufacture of roofing sheets or slabs was patented. Pumice is incorporated into the suspension of chrysotile and portland cement, and the mix is dewatered and subjected to pressure.[8]

A patent was issued in France for the use of pumice in the manufacture of a heat-resisting refractory concrete.[9]

A nonabrasive composition consisting of pumice and other materials to be used for recovering lost circulation in oil well drill holes was patented.[10]

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[4] Richter, D. H., W. U. Ault, J. P. Eaton, and J. E. Moore. The 1961 Eruption of Kilauea Volcano, Hawaii. U.S. Geol. Survey Proff. Paper 474–D, 1964, p. 34.

[5] Fiske, R. S., T. Matsuda. Submarine Equivalents of Ash Flows in Tokiwa Formation, Japan. Am. J. Science, v. 262, No. 1, January 1964, pp. 76–106.

[6] MacDonald, A. Gordon, and J. P. Eaton. Hawaiian Volcanoes During 1955. U.S. Geol. Survey Bull. 1171. 1964, pp. 1–170.

[7] Brick and Clay Record. V. 145, No. 6, December 1964, p. 69.

[8] Harshberger, N. P. Roofing Product. U.S. Pat. 3,137,100, June 16, 1964.

[9] Berthier, R. M. (assigned to Electricite de France). French Pat. 1,344,972, Oct. 28, 1963.

[10] Bodine, O. K. (assigned to Phillips Petroleum Co.). Drilling Mud and Method of Use. U.S. Pat. 3,150,726, Sept. 29, 1964.

Quartz Crystal

Electronic-Grade

By Benjamin Petkof[1]

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DOMESTIC raw quartz crystal consumption increased about 6 percent over the previous year. Finished crystal units exceeded 1963 production by 32 percent.

TABLE 1.—Salient electronic- and optical-grade quartz crystal statistics

	1955–59 (average)	1960	1961	1962	1963	1964
Imports of electronic- and optical-grade quartz crystal[1] thousand pounds	460	[2] 676	854	325	282	214
Value thousands	$833	[2] $504	$762	$731	$447	$399
Consumption of raw electronic-grade quartz crystal[3] thousand pounds	171	230	216	291	325	344
Production, piezoelectric units, number[4] thousands	5,573	8,712	9,822	11,787	13,614	17,920

[1] Imports through 1963 are mostly Brazilian pebble valued at $0.35 or more per pound; 1964—$0.50 per pound.

[2] Excludes quartz crystal imported from Brazil and accepted under Government agricultural barter contracts, 1959–60.

[3] For 1955 and subsequent years, data include some reworked scrap quartz crystal.

[4] For 1957–64 includes finished crystal units produced from reprocessed blanks, from raw quartz previously reported as consumption; and from imported blanks, 1957–62.

DOMESTIC PRODUCTION

No domestic production of natural electronic grade quartz was reported during 1964. At yearend six companies reported the production of manufactured quartz for electronic use. The companies were: American Hydrothermal, Inc., Groton, Mass., P. R. Hoffman Co., Carlisle, Pa., Sawyer Research Products, Inc., Eastlake, Ohio, Thermal-Kinetic Corp., Tuscon, Ariz., Transcom Electronics, Inc., Newport, R.I., and Western Electric Co., Inc., North Andover, Mass. Sawyer Research Products, Inc., reported sales of about 30,000 pounds of manufactured quartz. The Western Electric Co. continued to produce quartz for its own use and the use of its affiliated companies.

Total production capacity for manufactured quartz was estimated to be in excess of 80,000 pounds per year at the close of 1964.

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[1] Commodity specialist, Division of Minerals.

CONSUMPTION AND USES

Raw quartz crystal consumption for the production of piezoelectric units increased 19,000 pounds over the previous year's consumption. Manufactured quartz consumption continued its steady increase, and 34,982 pounds were consumed, an increase of 65 percent over 1963. An excess of 17 million finished quartz crystal units were produced from the 344,000 pounds of raw quartz crystal consumed during the year. The yield of finished quartz crystal from manufactured quartz is significantly greater than the yield from natural quartz crystal. However, no reliable value is available.

The Bureau of Mines received reports in 1964 from 38 crystal cutters, representing 39 consumers in 15 States. Finished piezoelectric units were produced by 37 of the consumers, the remainder produced only semifinished blanks. Twenty consumers, located in five States, used almost 90 percent of the reported raw quartz crystal consumption. Pennsylvania kept its position as the leading consumer with 45 percent of the total consumption. Kansas, Illinois, Massachusetts, and Missouri followed in the order listed.

Sixty-four producers fabricated piezoelectric units in 20 States. Of these 25 did not consume any raw quartz crystal but worked from partially processed quartz crystal blanks. Thirty-five plants in 10 States supplied almost 91 percent of the total output of finished crystal units. Total production was oscillator plates, 87 percent; and filter plates, telephone resonator plates, transducer crystals, and miscellaneous items, 13 percent. Filter plate production showed a slight increase. Resonator plate production increased substantially.

PRICES

Prices for natural electronic-grade quartz crystal sold to domestic users showed no significant change from 1963 prices. Approximate prices for the different weight classes follows:

Weight class (grams):	Price per pound
100–200	$2.00–$3.50
201–300	4.00–12.50
301–500	8.00–14.00
501–700	12.00–20.00
701–1,000	18.00–24.00
1,001–2,000	24.00–35.00

The price of manufactured quartz crystal was quoted by one large producer at $27.50 per pound in any quantity.

Lasca, used for manufacturing clear fused quartz and as feed material for manufactured quartz crystal, sold for about $0.50 per pound for first-quality material. The price of second-quality lasca was about $0.25 per pound.

FOREIGN TRADE

Imports of electronic- and optical-grade quartz crystal valued at more than $0.50 per pound were reported to be 214, 332 pounds valued at about $399,396. These figures are not comparable with those of previous years where imports valued over $0.35 per pound were reported. Brazil, maintaining its status as the largest supplier, furnished almost 97.5 percent of all the material imported. The remainder was supplied by Japan, West Germany, Argentina, and Canada.

Quartz crystal imports valued at less than $0.50 per pound totaled 569,608 pounds valued at $112,684. Brazil supplied all imports of this classification. This material, generally called lasca, was used principally for the manufacture of fused quartz and as feed material for the production of manufactured quartz crystal.

Exports of raw quartz amounted to $558,317, an increase of 6 percent over 1962. Japan, United Kingdom, Canada, West Germany, France, and Israel were the principal countries of destination. Data on the quantity of quartz crystal exported were not available.

Exports of quartz crystal manufactures, both material and synthetic, reach a value of $1,020,302. This exceeded the previous year by 16 percent.

WORLD REVIEW

Brazil.—Electronic- and fusing-grade quartz crystal exports totaled about 3.4 million pounds, an increase of almost 15 percent over 1963. This was valued at about Cr$.713 million. Breakdown of these data was not available by grade, but a substantial quantity of this material was lasca.

Canada.—During 1963 Quartz Crystal Mines, Ltd., Toronto produced a small quantity of quartz crystal for test purposes from its mine at Lyndhurst, Ontario. In 1963 imports of quartz crystal amounted to 12,000 pounds valued at $286,000.

TECHNOLOGY

At the eighteenth Annual Symposium on Frequency Control the following subjects were among the many papers discussed: The doping of cultured quartz; aging analysis of AT-cut quartz resonators of natural, cultured, and swept varieties; effect of electrode size on thickness shear vibrations of quartz plates; reliability of quartz crystal units; a new design for microminiature crystals; glass enclosed crystal units for temperature compensated oscillators; on the control of the temperature coefficient of frequency of AT-crystals; comparison of various methods used for determination of quartz crystal parameters in the frequency range 1 to 30 MC; crystal filters techniques; and high-Q, BT-cut, quartz resonator units.[2]

The production of four high quality cultured quartz crystals weighing from 12.2 to 12.7 pounds each was announced. The growth process required about 9 months and the crystals were found to be free of optical and electrical twinning.[3]

Plans and specifications were given for constructing a piezoelectric quartz composite oscillator designed to measure internal friction in metals and alloys. The characteristics of the system are listed, and detailed procedures for its operation were explained.[4]

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[2] U.S. Army Electronics Laboratories. Proceedings of the 18th Annual Symposium on Frequency Control. Fort Monmouth, N.J., May 1964, 597 pp.

[3] Electrochemical Technology. Cultured Quartz Crystals. V. 2, No. 9–10, September-October 1964, p. 303.

[4] Schwaneke, A. E. Construction and Operation of a Quartz Composite Oscillator. BuMines Rept. of Inv. 6419, 1964, p. 20.

The manufacture of new resistors by depositing a thin film of metal on glass or ceramic base materials under extremely high vacuum conditions was reported. These resistors are then sealed by evaporating a thin protective coating of quartz over the metal film rendering the product completely impervious to humidity. The precision film resistors are used in the microwave and other high frequency fields.[5]

Microstructures on faces of about seventy crystals of cultured quartz were examined by precision optical techniques. Growth spirals were observed on a number of prism faces on several specimens of cultured quartz of electronic grade synthesized by overseas manufacturers.[6]

The effects of temperature, impurities, and neutron irradiation on the dielectric relaxation of quartz crystals and fused silica were determined in a study of crystal lattice imperfections. Identification of impurities was made and a model of the imperfections was suggested.[7]

The presence of growth canals in quartz was related to the existence of colloidal impurities and crystal defects as well as conditions of crystal growth. The extent of canal formation was believed to be connected with anisotropy in impurity adsorption. Defect canals were observed to form parallel to the crystal-growth direction.[8]

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[5] Ceramic Industry. Film Resistors Sealed with Quartz. V. 83, No. 5, November 1964, p. 37.

[6] Joshi, M. S., and A. S. Vagh. Growth Spirals on Prism Faces of Cultured Quartz. American Mineralogist. V. 49, Nos. 11 and 12, November–December 1964, pp. 1771–1773.

[7] Stevels, J. M. Dielectric Properties of Quartz Crystals and Fused SiO_2 in Relations to Their Imperfections. Proc. Internat. School Phys. "Enrico Fermi" (Varenna, Italy). V. 27, 1963, pp. 368–392; Chem. Abs., v. 61, No. 9, October 1964, col. 101134.

[8] Tsinzerling, E. V. Canals in Quartz. Zap. Vses. Mineralog. Obshchestva, v. 93, No. 3, 1964, pp. 342–348; Chem. Abs., v. 61, No. 9, October 1964, col. 10115G.

Rare-Earth Minerals and Metals

By John G. Parker[1]

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ALTHOUGH domestic production of bastnaesite and monazite dropped over 35 percent, shipments for consumption rose about 125 percent. New domestic facilities were under construction for recovering europium, an important component of color television phosphors.

The national (strategic) and supplemental (barter) stockpiles totaled 15,779 tons of rare-earth oxides in rare-earth chloride, rare-earth sodium sulfate, bastnaesite, and monazite on December 31, 1964. This was a decrease of less than 0.5 percent in 1 year but still 426 percent over the revised stockpile objective of 3,000 short dry tons of rare-earth oxides (REO) set by Office of Emergency Planning (OEP) in March.

DOMESTIC PRODUCTION

Concentrate.—Shipments of bastnaesite concentrate from the Mountain Pass, Calif., property owned by Molybdenum Corporation of America were about 170 percent greater than for the previous year. In the same period, however, production decreased over 45 percent and yearend stocks were 12 percent less. The mine and milling facility has been operated only about one-third of the time since 1955 but, after completion by mid-1965 of a $1.1 million addition for extracting europium from the concentrate, it was expected to operate full time.[2] At the Skinner mine and beneficiation facility near Jacksonville, Fla., operated by Titanium Alloy Manufacturing Division, National Lead Co., production of byproduct monazite from titaniferous and zirconiferous beach sands decreased 8 percent but sales increased 41 percent. In accord with the announced closing of the operation by May 1965, stocks at yearend were 84 percent less than they were on December 31, 1963.

Metals and Compounds.—Rare-earth and yttrium-bearing concentrates were converted to compounds by the following chemical processors: American Potash & Chemical Corp., Rare Earth Division, West Chicago, Ill.; W. R. Grace & Co., Davison Chemical Division, Pompton Plains, N.J.; Molybdenum Corporation of America, York, Pa.; Research Chemicals Division, Nuclear Corporation of America, Phoenix, Ariz.; and Vitro Chemical Co., Chattanooga, Tenn.

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[1] Commodity specialist, Division of Minerals.

[2] Molybdenum Corporation of America. Annual Report. 1964, pp. 4–5.

Production of yttrium compounds, mostly of the oxide, by primary producers increased 125 percent over that of 1963. Research Chemicals and Michigan Chemical Corp., St. Louis, Mich., were principally producers of high-purity rare-earth and yttrium compounds, using ion-exchange and solvent extraction methods. Gallard-Schlesinger Chemical Manufacturing Corp., Atomergic Chemetals Division, Carle Place, N.Y., also refined yttrium oxide.

Rare-earth metals and alloys production, including that of misch metal and ferrocerium, by American Metallurgical Products Co., Inc., New Castle, Pa., and Ronson Metals Corp., Newark, N.J., decreased about 10 percent; that of high-purity metals, including yttrium by Lunex Co., Pleasant Valley, Iowa, and by American Potash, Michigan Chemical, and Nuclear Corp., rose significantly. Dresser Products, Inc., Great Barrington, Mass., fabricated about twice as much high-purity metals, mostly yttrium, as in 1963.

Vitro Chemical Co. announced, that, because of the presently limited market for rare-earth materials, an option agreement had been made to sell the Chattanooga facilities.

CONSUMPTION AND USES

The apparent industrial consumption of rare-earth elements and yttrium, as indicated by shipments of compounds from chemical processors, was about 2,320 tons of rare-earth and yttrium oxides. Sales of higher purity yttrium oxide destined for use in electronics and nuclear applications were only a small fraction of the total. In quantity, however, they were over twice those of 1963 but their unit value dropped 5 percent. Sales of rare-earth oxide powders for polishing flat glass, mirrors, precision optical equipment, and eyeglasses increased slightly and, although unit values decreased about 15 percent, the glass industry continued as the largest consumer of rare-earth compounds. Smaller quantities of special rare-earth compounds were used to color, discolor, and opacify glass and some ceramic glazes. Rare-earth products sold for use in steel dropped 23 percent in unit value although the quantity rose significantly. Shipments of metals, including misch metal, decreased over 20 percent in quantity, but the decrease in total value of only 5 percent from the previous year was an indication of greater sales of high-purity metals. Requirements of REO in the form of oxide and fluoride for arc-light carbons that emit bright white light decreased about 15 percent.

Alloys such as misch metal were used principally in the production of ferrocerium lighter flints but they were used also in desulfurizing cast iron, improving intermediate-temperature creep resistance in magnesium casting alloys, promoting hot workability and oxidation resistance of certain steel, and improving castability of steels and superalloys. Oxidation resistant rare-earth silicides were said to reduce chilling in nodular cast iron and to be effective in deoxidizing and desulfurizing stainless steel. The addition of about 2 percent didymium, predominantly neodymium and the balance mostly praseodymium, and some silver to magnesium produced a casting alloy with a very high yield strength.

It was reported that a rare-earth compound was being used commercially as a component in a crystalline aluminosilicate petroleum cracking catalyst, which has a very high activity, allows a recovery of up to 20 percent more gasoline than some other catalysts, and is stable at high temperatures and in steam atmospheres.[3]

An outstanding example of the use of high-purity material was that of europium as an activator in phosphors to produce a brighter color television picture with truer red and a better color balance. In one phosphor, europium is added to yttrium orthovanadate, the ratio being 1 europium ion to 19 yttrium ions. Europium also was reported to be effective with gadolinium orthovanadate. Other possibilities were certain rare-earth borates and phosphates activated with europium.[4] The luminescent properties of some rare-earth elements, including europium, terbium, praseodymium, and neodymium, have led to their use as activators in crystal, glass, plastic, and liquid laser systems.

With the exception of the new use in color television phosphors, the most important use of yttrium to date has been in microwave devices in yttrium iron garnet (YIG) and, more recently, in yttrium aluminum garnet (YAG) doped with a small quantity of neodymium. This latter type of garnet was said to operate at room temperature with cooling by ordinary tap water and to support continuous laser action using a tungsten-filament light source.[5]

Because of their high thermal-neutron cross sections, some rare-earth oxides are excellent long-lived absorbers in nuclear reactor cores. For instance, europium oxide sintered with either tungsten or molybdenum oxides, then ground and compacted with stainless steel powder and resintered, forms a stable hydration-resistant material for reactor control rods.[6] Production of extruded and vitrified neutron-absorbing ceramic rods by adding 4 to 8 percent gadolinia, samaria, or didymia to the usual clay-feldspar-alumina batch was described.[7] A thermal-neutron absorbing paint was developed which uses oxides of gadolinium, samarium, or europium as part of the pigment.[8]

Radioisotopes of rare-earth metals, such as ytterbium 169, can be used in portable units for industrial radiography of thin sections of steel and aluminum. Yttrium oxide is used to stabilize zirconia structure in crucibles; it is used also as a protective refractory coating because of its high melting point.

STOCKS

Inventories of rare-earth mineral concentrates, including bastnaesite and monazite, held by chemical processors and a mining company were about 13 percent less at yearend than at the same time in 1963. Monazite stocks decreased more percentagewise than did those of bastnaesite.

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[3] Plank, C. J., E. J. Rosinski, and W. P. Hawthorne. Acidic Crystalline Aluminosilicates—New Superactive, Superselective Cracking Catalysts. Amer. Chem. Soc., Div. Petrol. Chem. Preprints, v. 9, No. 3, August 1964, pp. 325–334.

[4] Bril, A., and W. L. Wanmaker. Fluorescent Properties of Some Europium-Activated Phosphors. J. Electrochem. Soc., v. 111, No. 12, December 1964, pp. 1363–1368.

[5] Chemical Week. V. 95, No. 21, Nov. 21, 1964, p. 74.

[6] McNees, Robert A., and Ralph A. Potter (assigned to the U.S. Atomic Energy Commission). Stabilized Rare Earth Oxides for a Control Rod and Method of Preparation. U.S. Pat. 3,117,372, Jan. 14, 1964.

[7] Goode, Allen Davidson (assigned to Doulton & Co., Ltd., London). Ceramic Materials. British Pat. 942,945, Nov. 27, 1963.

[8] Klein, Nathan (assigned to the Department of the Army). Rare Earth Shield. U.S. Pat. 3,123,576, Mar. 3, 1964.

Imports of monazite by processors, obtained from Australia and Malaysia, decreased 77 percent.

A 50-percent decrease in stocks of the intermediate material, rare-earth sulfate, indicated that this material would probably need replenishment in the near future from the processing of monazite. Total stocks of other rare-earth and yttrium compounds, expressed as REO and including those of high purity, increased nearly 4 percent but those of yttrium oxide decreased 9 percent. Misch metal stocks decreased about 11 percent but those of pure metals remained about the same.

PRICES

Nominal quotations on imported monazite concentrates have remained unchanged since 1960. According to E&MJ Metal and Mineral Markets they were, per pound, cif U.S. ports: Massive, 55 percent total rare-earth oxides including thoria, 14 cents; sand, 55 percent at 10 to 15 cents, 66 percent at 18 cents and 68 percent at 20 cents.

New price lists were issued by American Potash & Chemical Corp., Lunex Co., Michigan Chemical Corp., Research Chemicals Division of Nuclear Corporation of America, and Gallard-Schlesinger Chemical Manufacturing Corp. With the exception of a slight decrease in the price of ceric hydrate, those of production chemicals from the largest chemical processor remained the same as in 1963. Cerium hydrates, of two purity designations and in 100-pound lots or greater, were quoted at $1.40 and $1.74 per pound; optical grade cerium oxide in 50-pound bags was quoted at $1.85 to $1.90 per pound.[9]

Prices of most of the purified oxides produced by one refiner remained the same as in 1963; those of europium, holmium, and thulium oxides were increased significantly and several others, including dysprosium oxide, were decreased. The prices of yttrium oxide from three producers varied according to company, purity, and lot size from $42 to $400 per pound; those of europium oxide, with the same qualifications ranged from $350 to $1,000 per pound. The lowest priced high-purity oxide was that of cerium, available at a price as low as $7 per pound. The highest price noted on a 1964 list was for 99.9 percent pure lutetium oxide at $4,000 per pound. Most prices for purified chlorides and fluorides at a small refinery increased, some over 100 percent. Prices by a larger refinery remained generally stable, although prices of gadolinium and dysprosium salts decreased, whereas increased prices were quoted for salts of the scarcer elements, such as holmium and thulium. However, the prices at the large refinery were still significantly lower than those quoted by two other producers.

Purified rare-earth metals, available from five producers and dependent upon purity designation, form, and lot size, ranged from $70 per pound of 99.9 percent pure cerium to $8,750 per pound of 99.5 percent pure lutetium. Europium metal was quoted at $1,200 to $3,500 per pound; yttrium metal ranged from $75 per pound for commercial grade to $300 per pound for nuclear grade to $500 per pound of double-distilled grade.

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[9] Oil, Paint and Drug Reporter. Current Market Quotations. V. 185, Nos. 1–26, Jan. 6–June 29, 1964; v. 186, Nos. 1–26, July 6 to Dec. 28, 1964.

Misch metal ingot prices were relatively unchanged with up to $8 per pound being asked for small lots of a special cerium-free misch metal. Yttrium alloy innoculants, including so-called yttrium misch metal, ranged from $24 to $50 per pound.

FOREIGN TRADE

Imports.—Cerium oxide totaling 2,302 pounds valued at $5,737 was received from France, Austria, West Germany, and Switzerland. That from France was 87 percent by quantity and 80 percent by value of the total. Almost 90 percent of the $10,355 value of rare-earth metals imports, including yttrium was for material from West Germany, the remainder for material from the United Kingdom. Imports of rare-earth alloys, including misch metal, from Austria totaled 5,070 pounds with a value of $7,069. Pyrophoric alloys, including ferrocerium and totaling 9,621 pounds worth $47,895, were imported from six countries. These included Japan with over 40 percent of the total quantity and 45 percent of the value and Austria with over 26 percent of the quantity and nearly 17 percent of the value. Although United Kingdom shipped only 13 percent of these alloys to the United States, their unit value was the highest, raising their value to 25 percent of the total pyrophoric alloy imports. Imports of monazite concentrate, reported by the Bureau of the Census as received from Ceylon, Australia, and Malaysia, totaled 2,105 short tons valued at $186,458, about one-third by quantity and one-fourth by value of those received in 1963. About 70 percent was received from Australia. Reports to the Bureau of Mines indicated that chemical processors had received about 20 percent fewer imports than those recorded by Census.

Exports. Shipments of 1,637,142 pounds of cerium ore, metals, and alloys worth $399,573 were made to eight countries. This was nearly a twelvefold increase in quantity and a ninefold increase in value over shipments made in 1963. The United Kingdom was the recipient of over 70 percent by quantity and nearly 50 percent by value. Other countries receiving these materials from the United States were principally West Germany and Japan, with smaller quantities going also to Canada, the Netherlands, France, Mexico, and Israel. Exports of ferrocerium (lighter flints) to 20 countries decreased over 6 percent and totaled 37,455 pounds valued at $139,279. The largest recipient country was the United Kingdom (22,500 pounds valued at $59,580), followed by Canada (6,600 pounds, $33,000) and Australia (2,480 pounds, $9,485).

WORLD REVIEW

Australia.—Exports of 948 short tons of monazite concentrate from January through June were nearly 13 percent lower than in the same period of the preceding year. A slightly lower grade of monazite concentrate was produced in the first 6 months of 1964 compared with that in the same period of 1963;[10] the quantity produced was about the same.

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[10] Commonwealth Bureau of Census and Statistics (Canberra). The Australian Mineral Industry. Pt. 2—Quarterly Review, quarter ended June 30, 1964. V. 17, No. 2, December 1964, pp. 7, 20.

TABLE 1.—World production of monazite concentrates by countries

(Short tons)

Country	1962	1963	[p] 1964
South America: Brazil	3,858	1,874	NA
Asia:			
Ceylon	---	---	25
India	[1] 3,233	[1] 2,429	NA
Indonesia	153	NA	NA
Korea, South [2]	755	NA	NA
Malaysia (exports)	702	991	340
Africa:			
Malagasy Republic	702	678	[3] 947
Nigeria	10	12	NA
South Africa, Republic of	5,326	2,300	NA
Oceania: Australia	912	2,310	2,270
Free-world total [e]	16,300	12,000	8,500

[e] Estimate. [p] Preliminary. NA Not available.
[1] Year ended March 31 of year following that stated.
[2] Reported as concentrate containing 45 to 55 percent R_2O_3; also reported as 30 percent Ce, which may be high.
[3] Exports.

Brazil.—At Cumuruxatiba near Prado in Bahia a plant operated by Comissão Nacional de Energia Nuclear separated monazite and other heavy minerals from area sand deposits estimated at 180,000 tons. The heavy black sand was concentrated hydraulically in Humphreys spirals and dried in a rotating oven; then the monazite was separated from other heavy minerals by electrostatic and electromagnetic means. Monazite constituted nearly 20 percent of the heavy mineral concentrate which was produced at the rate of 1,200 tons per month. After bagging, the monazite concentrate was shipped to Saõ Paulo.

A mining tax of 8 percent, including 3 percent to Federal and 5 percent to State and municipal Governments, was assessed on all Brazilian mineral producers. At the exchange rate in effect in 1964 this ranged from $0.75 per metric ton of clean monazite sand to $5.25 per metric ton of samarskite and fergusonite, which are rare-earth-bearing multiple oxide minerals.

India.—The plant operated by Indian Rare Earths Ltd. at Alwaye in Kerala State processed 2,677 short tons of monazite in the fiscal year ending March 31, 1964. This reduction of 17 percent in production from the previous fiscal year was due to power cuts in Kerala. Rare-earth chloride production dropped about 8 percent to 3,327 tons but exports of chloride valued at $1.1 million (5.2 million rupees) were 15 percent greater. A 10-ton-per-month cerium fluoride plant was being built at Alwaye to meet rising demand by the carbon-arc industry. At Manavalakurichi in Madras State production of monazite at the Government-owned plant of Travancore Minerals Ltd. dropped from 2,651 tons in fiscal year 1962–63 to 2,306 tons in fiscal year 1963–64. This decrease was believed due to the poor quality of the tailings.

Japan.—A new publication showed the names, addresses, types of operation, and capacities of Japanese producers of rare-earth oxides, fluorides, misch metal, and ferrocerium lighter flints. Prices and data on imports and exports in 1962 and 1963 also were given.[11]

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[11] Japan Society of Newer Metals (Tokyo, Japan). Current Situation of Newer Metals in Japan. 1964, 45 pp.

TECHNOLOGY

Scientists attending the Fourth Rare Earth Research Conference in Phoenix, Ariz., presented results of research on magnetic and electrical properties of rare-earth compounds, physical properties and phase equilibria of rare-earth metals and alloys, and optical properties, solution chemistry, and solid state chemistry of rare-earth materials. At the conference, a new French technique was described for purifying europium and samarium metals by sublimation in an inert gas-filled solar furnace.

The Bureau of Mines continued research on improving rare-earth ore beneficiation techniques and assessing the value of selective chelating resins and other low-cost agents in solvent extraction separation of rare-earth mixtures. Other projects included the continuous recovery of high-purity cerium metal from a fused salt bath in a newly designed electrowinning cell, measurement of the electrical properties of cerium metal, determination of equilibrium data on two binary systems containing gadolinium, development of a rapid gravimetric technique to determine rare-earth elements, study of the effect of small quantities of yttrium and rare-earth metals on electrorefined vanadium, and determination of optimum conditions for producing ceria powders commercially.[12]

A Finnish scientist reported the first isolation of promethium in its natural form. From about 6,500 tons of apatite processed at a fertilizer plant, Professor Olavi Erämetsä recovered about three-thousandths of an ounce of promethium.[13]

Allanite, a common rare-earth silicate, was found in veins and cavities in granitic rock in North Wales, as well as selectively replacing potassium feldspar in the granite itself.[14] Cenosite, one of a small group of minerals in which yttrium is a major component, was discovered in a thorite-bearing vein near Porthill, Idaho. This mineral, hitherto known only from Cotopaxi, Colo., and from five foreign localities, was isolated and identified after microspectroscopic examination showed an absorption band characteristic of a mineral species containing yttrium subgroup elements.[15] Relatively extensive deposits of xenotime and monazite were reported to occur, usually in biotite-rich lenses, pods, and folia, in Precambrian gneissic rocks of Riverside County, Calif. Methods for concentrating the xenotime and computing reserves were described.[16] Of the 10 domestic occurrences of bastnaesite, only those in the Gallinas Mountains of New Mexico were found to have been formed at temperatures below 200° C. These epithermal vein and breccia fillings occur in faulted, intensely brecciated Permian sandstone closely associated with alkalic Tertiary intrusives.[17] A newly discovered rare-earth pegmatite in Texas is similar mineralogically to the famous Baringer Hill pegmatite, now inundated by a lake. Minor bastnaesite is present and the four primary rare-earth minerals—allanite, gadolinite, fergusonite, and cyrtolite—were found in three general associations.[18]

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[12] Bauer, D. J., and R. E. Lindstrom. Naphthenic Acid Solvent Extraction of Rare-Earth Sulfates. BuMines Rept. of Inv. 6396, 1964, 19 pp.

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[13] Bureau of Mines. Mineral Trade Notes. V. 60, No. 3, March 1965, p. 22.

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A new process was developed for extracting and separating rare-earth elements and thorium from calcium-bearing ores. The finely ground ore was treated with an aqueous solution of sulfur dioxide, and calcium was selectively precipitated and separated as the sulfate from the aqueous liquid reaction product. The thorium and rare-earth elements in the filtrate were then separated.[19]

Attempts were made to synthesize arsenic-containing amines which might be used as coordination agents capable of separating ions with radii above and below the maximum and minimum radii of rare-earth ions and to find ligands which possibly might be used to stabilize oxidation states less than and greater than three, thereby making possible more satisfactory separations of tetravalent cerium and divalent samarium, europium, and ytterbium.[20] Other new techniques which were summarized include ion-exchange chromatography, ion-exchange membranes, solvent extraction, and amalgam extraction. Ion exchange was described as the best general-purpose means for preparing high-purity rare-earth elements, while solvent-extraction systems, even though allowing rapid group separations, were thought more useful as adjuncts to ion-exchange separation.[21]

Analytical techniques investigated included thermogravimetric, metallographic, differential thermal, and mass spectrographic methods.[22]

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[20] Gannon, J. A., C. A. Erikson, and D. W. Cook. Separation of the Rare Earth Elements. U.S. Dept. of Commerce, Office of Tech. Services Rept. AD 607286, Apr. 15, 1964, 8 pp.

[21] Topp, N. E. Modern Techniques for Separating the Rare-Earth Elements. J. Less-Common Metals (Amsterdam, Netherlands), v. 7, No. 6, December 1964, pp. 411–419.

[22] Etter, D. E., and J. E. Selle. Metallographic and Differential Thermal Analyses of the Purity of Cerium. Trans. AIME, v. 230 (Met. Soc.), No. 3, April 1964, pp. 591–593.

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Wilfong, Roy L., Louis P. Domingues, and LeRoy R. Furlong. Thermogravimetric Analysis of Five Salts of Praseodymium, Neodymium, and Samarium. J. Am. Ceram. Soc., v. 47, No. 5, May 1964, pp. 240–241.

X-ray diffraction techniques showed that high pressure transformed lanthanum, praseodymium, and neodymium from the normal hexagonal to face-centered cubic structure.[23] Unit cell dimensions of some high-pressure allotropic forms of lanthanum, praseodymium, and neodymium apparently never before had been reported.[24] In alloys of such rare-earth metals as gadolinium, terbium, and dysprosium with magnesium subjected to high temperatures, it was found that the high-temperature body-centered cubic phase decomposed to a hexagonal rare-earth magnesium solid solution and a simple cubic peritectic AB-type compound.[25] It was reported that a high-temperature gamma phase previously proposed for cerium is probably cerium monoxide containing small quantities of silicon and possibly boron in solid solution.[26] Measurements were made of lattice spacings for pure cerium, thorium, and yttrium and for alloys in the yttrium-cerium, yttrium-lanthanum, and thorium-cerium systems. It was suggested that the effective atomic diameter of cerium in thorium-rich alloys varies with temperature, with changes in the strain energy of alloying being important.[27] Lattice spacings also were measured for a series of zirconium-rich zirconium-cerium alloys annealed to equilibrium at temperatures from 655° to 850° C, with solid solubility of cerium increasing to 6 atomic percent at the highest temperature. The strain energy is greater in this system, the cerium contraction is also greater, and the effective atomic diameter of cerium in solid solution is less than it is in the thorium-cerium alloys.[28] High-purity and commercial grade yttrium were tested for oxidation characteristics in air at temperatures between 500° and 1,400° C and between 600° and 900° C, respectively. An oxide layer on the pure metal afforded excellent protection below about 875° C but broke down at higher tempreatures; fluorine and silicon adversely affected the oxidation rate in commercial grade yttrium.[29] Other measurements were made of oxidation rates at elevated temperatures. The sesquioxides formed according to the linear weight-gain law.[30] Magnetic properties of various rare-earth metals, alloys, and compounds were studied. Iron in the form of Fe_2Gd was believed to be responsible for the anomalous magnetic behavior of gadolinium above 500° C.[31]

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[27] Harris, I. R., and G. V. Raynor. The Constitution of Yttrium-Cerium and Yttrium-Lanthanum Alloys, With Special Reference to Lattice Spacings. J. Less-Common Metals (Amsterdam, Netherlands), v. 7, No. 1, July 1964, pp. 1–10.

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[28] Harris, I. R., and G. V. Raynor. The Electronic State of Cerium in Zirconium-Cerium Alloys. J. Less-Common Metals (Amsterdam, Netherlands), v. 6, No. 1, January 1964, pp. 70–80.

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[30] Phillips, W. L., Jr., Oxidation of Several Lanthanide Elements. J. Less-Common Metals (Amsterdam, Netherlands) v. 7, No. 2, August 1964, pp. 139–143.

[31] Arajs S., and R. V. Colvin. Effect of Iron Impurity on the Magnetic Susceptibility of Gadolinium at Elevated Temperatures. J. Less-Common Metals (Amsterdam, Netherlands), v. 7, No. 5, November 1964, pp. 336–340.

Phase equilibrium studies were conducted on binary systems and other systems containing rare-earth elements. A new rare-earth aluminum compound stable at high temperature was determined,[32] two congruent and three incongruent compounds of cerium and copper were discovered,[33] new values were obtained for solidus and liquidus temperatures and compound stabilities in a reevaluation of the neodymia-silica system,[34] and the transition temperature from the monoclinic to high-temperature tetragonal form was found to be considerably higher in rare-earth tantalates than in the columbates.[35]

A previously unreported compound was formed when europium trihydroxide was decomposed thermally in air. Data collected by X-ray diffraction indicated the trihydroxide is hexagonal and the new compound, EuOOH, is possibly orthorhombic.[36] A new method for preparing high-purity rare-earth hexaborides entails vacuum heating of certain rare-earth oxides with elemental boron.[37]

Crystals of rare-earth and yttrium phosphates, some exhibiting distinctive fluorescence phenomena, were grown by dissolving and reacting rare-earth and yttrium oxides in molten lead pyrophosphate at elevated temperatures and crystallizing the phosphate by cooling.[38] Europium was said to be the most effective laser activator in yttrium oxide; fluorescence was found to occur in rare-earth oxide phosphors only in matrices where the cation has no unpaired electrons; and data on fluorescence spectra and lifetimes for europium and terbium chelates were given.[39] Neodymium-doped yttrium oxide was said to be better than neodymium-doped calcium tungstate, the other optically pumped laser material operating at room tempertature.

Photochromic glass materials, darkening upon exposure to certain wavelengths of light and quickly regaining transparency upon removal of the light, have been suggested for sunglasses, windshields, and windowpanes.[40]

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[37] Bliznakov, G., and P. Peshev. The Preparation of Cerium, Praseodymium, and Neodymium Hexaborides. J. Less-Common Metals (Amsterdam, Netherlands), v. 7, No. 6, December 1964, pp. 441–446.

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[40] Chemical Week. Chemical Light Switch. V. 94, No. 7, Feb. 15, 1964, pp. 51–52.

Salt

By William H. Kerns[1]

INCREASING consumption of sodium chloride (salt) in the chemical industry for producing chlorine-caustic and soda ash, and an expanded use for deicing highways resulted in a record high U.S. salt output in 1964. Production was 3 percent above that of 1963, a gain of nearly 1 million tons.

DOMESTIC PRODUCTION

Texas was the leading salt-producing State followed closely by Louisiana, New York, Ohio, and Michigan.

TABLE 1.—Salient salt statistics

(Thousand short tons and thousand dollars)

	1955–59 (average)	1960	1961	1962	1963	1964
United States:						
Sold or used by producers	23,563	25,479	25,707	28,807	r 30,641	31,623
Value [1]	$141,125	$161,214	$160,223	$174,841	r $184,589	$200,706
Imports for consumption	568	1,057	1,050	1,374	r 1,516	2,340
Value	$3,169	$4,484	$3,755	$5,097	r $5,112	$5,677
Exports	384	420	642	671	781	594
Value	$2,602	$2,548	$3,876	$3,638	$4,140	$3,373
Consumption, apparent	23,747	26,116	26,115	29,510	r 31,376	33,369
World: Production	79,600	93,500	93,500	100,900	104,700	108,800

r Revised.

[1] Values are f.o.b. mine or refinery and do not include cost of cooperage or containers.

Salt was produced by 57 companies at a total of 96 plants. Ten companies, each producing more than 1 million tons, operated 40 plants, which in aggregate accounted for 86 percent of the total U.S. salt output; 14 companies, each producing less than 1 million tons but more than 100,000 tons of salt, operated 21 plants and together supplied 12 percent of the total; and 33 companies, each producing less than 100,000 tons, operated 35 plants and produced the remaining 2 percent of the total U.S. salt output.

Seven plants, each with an output of over 1 million tons of salt, together accounted for 43 percent of the total U.S. salt production; 14 plants, 500,000 to 1 million tons, 31 percent; 31 plants, 100,000 to 500,000 tons, 22 percent; 23 plants, 10,000 to 100,000, 4 percent; and 21 plants, less than 10,000 tons, less than 1 percent.

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[1] Commodity specialist, Division of Minerals.

TABLE 2.—Salt sold or used by producers in the United States

(Thousand short tons and thousand dollars)

State	1963		1964	
	Quantity	Value	Quantity	Value
California	1,716	(1)	1,525	(1)
Kansas [2]	924	$11,993	930	$11,799
Louisiana	6,199	30,450	6,401	36,056
Michigan	4,244	33,656	4,345	35,711
New Mexico	[r] 54	[r] 472	62	559
New York	4,782	34,228	4,816	34,216
Ohio	4,245	29,682	4,537	31,092
Oklahoma	4	26	6	41
Texas	5,965	22,355	6,410	28,797
Utah	325	3,462	371	3,848
West Virginia	(1)	(1)	1,033	3,666
Other States [3]	2,183	18,265	1,187	14,921
Total	[r] 30,641	[r] 184,589	31,623	200,706
Puerto Rico	8	131	5	74

[r] Revised.

[1] Included with "Other States" to avoid disclosing individual company confidential data.

[2] Quantity and value of brine included with "Other States."

[3] Includes States indicated by footnote 1 and Alabama, Colorado, Hawaii, Kansas (brine only), Nevada, North Dakota, and Virginia.

Of the 982,000-ton advance in salt output in the United States in 1964, 842,000 tons, or 85 percent, resulted from the increase in the production and use of salt in brine (produced as brine and used as such). Output of rock salt increased 209,000 tons or 2.5 percent above 1963, but evaporated salt declined 69,000 tons or 1.4 percent in tonnage sold or used.

Cudahy Packing Co. announced that its subsidiary, American Salt Corp., planned to build a $2 million plant at Midland, Mich., to produce a full line of salt products beginning in 1965. American Salt said that it had made a long-term agreement with The Dow Chemical

TABLE 3.—Salt sold or used by producers in the United States, by methods of recovery

(Thousand short tons and thousand dollars)

Method of recovery	1963		1964	
	Quantity	Value	Quantity	Value
Evaporated:				
Bulk:				
Open pans or grainers	309	$8,168	301	$8,024
Vacuum pans	2,334	50,802	2,422	53,262
Solar	1,766	10,136	1,592	10,107
Pressed blocks	[r] 362	[r] 7,914	387	8,659
Total	[r] 4,771	[r] 77,020	4,702	80,052
Rock:				
Bulk	8,285	50,059	8,489	50,565
Pressed blocks	60	1,589	65	1,725
Total	8,345	51,648	8,554	52,290
Salt in brine (sold or used as such)	17,525	55,921	18,367	68,364
Grand total	[r] 30,641	[r] 184,589	31,623	200,706

[r] Revised.

TABLE 4.—Evaporated salt sold or used by producers in the United States

(Thousand short tons and thousand dollars)

State	1963		1964	
	Quantity	Value	Quantity	Value
Kansas	435	$9,669	438	$9,485
Louisiana	250	5,987	251	6,080
Michigan	926	18,724	941	20,597
New York	593	13,794	628	14,501
Ohio	(1)	(1)	603	13,315
Oklahoma	2	20	3	33
Utah	315	3,390	360	3,776
Other [2]	2,250	[r] 25,436	1,478	12,265
Total	[r] 4,771	[r] 77,020	4,702	80,052
Puerto Rico	8	131	5	74

[r] Revised.

[1] Included with "Other" to avoid disclosing individual company confidential data.

[2] Includes States indicated by footnote 1, and California, Hawaii, Nevada, New Mexico, North Dakota, Texas, and West Virginia (1963).

TABLE 5.—Rock salt sold by producers in the United States

(Thousand short tons and thousand dollars)

Year	Quantity	Value	Year	Quantity	Value
1955–59 (average)	5,565	$36,530	1962	7,726	$46,874
1960	6,466	44,983	1963	8,345	51,648
1961	6,439	42,950	1964	8,554	52,290

TABLE 6.—Pressed-salt blocks sold by original producers of salt in the United States

(Thousand short tons and thousand dollars)

Year	From evaporated salt		From rock salt		Total	
	Quantity	Value	Quantity	Value	Quantity	Value
1955–59 (average)	282	$5,856	54	$1,227	336	$7,083
1960	330	7,575	60	1,526	390	9,101
1961	357	7,866	63	1,661	420	9,527
1962	366	8,034	61	1,576	427	9,610
1963	[r] 362	[r] 7,914	60	1,589	422	9,503
1964	387	8,659	65	1,725	452	10,384

[r] Revised.

Co. of Midland to receive byproduct brine slurry from the adjacent Dow plant. From this brine American Salt expects to recover, process, package, and market salt.

The International Salt Co. completed its program of consolidating its Ludlowville, N.Y., evaporating plant with its Watkins Glen, N.Y., evaporating plant and reported that output from the Watkins Glen plant would be increased 10 percent in 1965. In addition, International Salt was planning construction of a solar evaporation salt plant on the island of Bonaire in the Netherlands Antilles to have a production capacity of 450,000 tons per year.

Diamond Crystal Salt Co. continued the development of its Long Island, Bahamas, solar salt plant installation, and reportedly will produce small quantities of salt from this location in 1965, with increased output planned in subsequent years. Salt production from the Bonaire and Long Island operations would be primarily for distribution to municipal and industrial users along the eastern seaboard of the United States.

CONSUMPTION AND USES

Over 12 million tons, or 39 percent of the total salt output, was used in making chlorine and its coproduct, caustic soda. The second largest use of salt was for manufacturing sodium carbonate (soda ash), which accounted for over 7 million tons, or 22 percent of the total salt output. Manufacture of all other chemicals required 1.6 million tons of salt, or 5 percent of the total. The total salt consumption by the chemical industry was 21 million tons, or 67 percent of all salt sold or used. Of the total salt used in the chemical industry, 18 million tons, or 86 percent, was consumed as brine.

Next in importance to the chemical industry use of salt is the highway use for snow and ice removal and for roadbed stabilization. This use, as shown in table 7 under "States, counties, and other political sub-

TABLE 7.—Salt sold or used by producers in the United States, by classes and consumers or uses

(Thousand short tons)

Consumer or use	1963				1964			
	Evaporated	Rock	Brine	Total	Evaporated	Rock	Brine	Total
Chlorine	(1)	(1)	10,121	11,985	(1)	(1)	10,369	12,293
Soda ash	(1)	(1)	6,508	6,513	(1)	(1)	7,073	7,083
Soap (including detergents)	(1)	(1)	-------	35	24	6	-------	30
All other chemicals	(1)	(1)	733	1,418	326	548	713	1,587
Textile and dyeing	141	119	-------	260	89	101	1	191
Meatpackers, tanners, and casing manufacturers	333	414	-------	747	324	412	-------	736
Fishing	(1)	(1)	-------	26	(1)	(1)	-------	29
Dairy	59	4	-------	63	42	3	-------	45
Canning	185	54	-------	239	181	54	-------	235
Baking	(1)	(1)	-------	115	105	4	-------	109
Flour processors (including cereal)	60	8	-------	68	56	8	-------	64
Other food processing	120	18	-------	138	116	15	-------	131
Ice manufacturers and cold-storage companies	16	22	-------	38	17	21	-------	38
Feed dealers	r 631	415	-------	r 1,046	626	420	-------	1,046
Feed mixers	273	110	-------	383	290	116	-------	406
Metals	51	77	-------	128	54	83	-------	137
Ceramics (including glass)	7	8	-------	15	6	9	-------	15
Rubber	12	28	67	107	(1)	(1)	55	77
Oil	(1)	72	(1)	173	60	64	92	216
Paper and pulp	(1)	123	(1)	135	(1)	147	(1)	201
Water-softener manufacturers and service companies	(1)	293	(1)	507	236	330	4	570
Grocery stores	576	286	-------	862	607	298	-------	905
Railroads	14	37	-------	51	7	33	-------	40
Bus and transit companies	(1)	(1)	-------	33	(1)	(1)	-------	45
States, counties, and other political subdivisions (except Federal)	(1)	3,707	(1)	3,909	(1)	3,755	(1)	3,975
U.S. Government	19	55	-------	74	24	70	-------	94
Miscellaneous	r 1,103	419	51	r 1,573	911	396	18	1,325
Undistributed [2]	r 1,171	2,076	45	-------	601	1,661	42	-------
Total	r 4,771	8,345	17,525	r 30,641	4,702	8,554	18,367	31,623

r Revised.

[1] Included with "Undistributed" to avoid disclosing individual company confidential data.

[2] Includes items indicated by footnote 1 and some exports and consumption in overseas areas administered by the United States.

divisions (except Federal)," accounted for nearly 4 million tons of salt, or 13 percent of the total salt output. Salt sold to grocery stores (table 7) is assumed to be used as table salt, representing 3 percent of the total. A growing use of salt was in water softening, which consumed 2 percent of the total U.S. salt output.

TABLE 8.—Distribution (shipments) of evaporated and rock salt produced in the United States, by destination

(Thousand short tons)

Destination	1963		1964	
	Evaporated	Rock	Evaporated	Rock
Alabama	27	254	29	283
Alaska	4	-----	3	-----
Arizona	[r] 21	19	(1)	15
Arkansas	13	64	16	67
California	725	65	790	(1)
Colorado	78	25	82	29
Connecticut	15	90	16	53
Delaware	7	17	7	8
District of Columbia	5	12	4	40
Florida	23	85	23	92
Georgia	45	79	45	84
Hawaii	4	-----	4	-----
Idaho	29	2	32	2
Illinois	243	569	236	503
Indiana	133	278	130	283
Iowa	139	199	143	205
Kansas	76	171	74	173
Kentucky	37	206	42	220
Louisiana	29	177	28	204
Maine	21	134	(1)	111
Maryland	42	173	63	143
Massachusetts	47	256	61	283
Michigan	204	337	198	346
Minnesota	133	120	122	169
Mississippi	18	78	19	86
Missouri	82	166	83	151
Montana	33	1	36	1
Nebraska	80	71	76	80
Nevada	21	157	21	(1)
New Hampshire	5	136	4	140
New Jersey	146	336	146	404
New Mexico	[r] 11	45	12	56
New York	220	1,500	229	(1)
North Carolina	98	123	101	133
North Dakota	30	4	29	6
Ohio	257	681	255	724
Oklahoma	28	49	31	59
Oregon	46	-----	48	-----
Pennsylvania	165	507	169	529
Rhode Island	9	30	9	(1)
South Carolina	28	21	32	20
South Dakota	35	24	37	22
Tennessee	119	241	122	238
Texas	[r] 96	260	94	242
Utah	73	5	102	7
Vermont	6	84	7	87
Virginia	74	115	78	118
Washington	167	-----	159	-----
West Virginia	25	70	25	69
Wisconsin	134	189	126	155
Wyoming	16	2	18	11
Other [2]	649	118	486	1,903
Total	[r] 4,771	8,345	4,702	8,554

[r] Revised.

[1] Included with "Other" to avoid disclosing individual company confidential data.

[2] Includes item indicated by footnote 1, and shipments to Territories, overseas areas administered by the United States, and Puerto Rico, exports, and some shipments to unspecified destinations.

PRICES

Quotations for rock and table salt in carlots, f.o.b. New York, by Oil, Paint and Drug Reporter have remained steady since February 1958 at $1.09 per 100 pounds for rock salt in paper bags and $1.34 per 100 pounds for vacuum common fine table salt. The average value of salt sold or used by producers in 1964, f.o.b. mine, as reported to the Bureau of Mines was $6.11 per ton for rock salt (total of bulk and pressed block), $17.02 per ton for evaporated salt (open pans or grainers, vacuum pans, solar, and pressed block), and $3.72 per ton for salt in brine. Solar salt alone was valued at an average of $6.35 per ton.

FOREIGN TRADE

Imports of salt for consumption was 7.4 percent of the total U.S. salt production. About 58 percent of the imports came from Canada and 23 percent from Mexico. All of the imports were bulk salt and salt in brine except for 10,442 tons, or less than 0.5 percent of the total, which was packaged in bags, sacks, or barrels. The salt came in through 24 customs districts.

TABLE 9.—Salt shipped to the Commonwealth of Puerto Rico and overseas areas administered by the United States

Area	1963		1964	
	Short tons	Value	Short tons	Value
American Samoa	197	$7,282	127	$5,024
Guam	116	9,934	101	12,013
Puerto Rico	9,543	845,390	13,600	1,141,849
Virgin Islands	165	18,324	138	15,212

Source: Bureau of the Census.

TABLE 10.—U.S. imports for consumption of salt, by countries [1]

Country	1963		1964	
	Short tons	Value	Short tons	Value
North America:				
Bahamas	[r] 218,056	$843,058	292,133	$1,155,339
Canada	[r] 784,407	[r] 3,382,263	1,359,082	3,433,787
Dominican Republic	---	---	23,167	45,725
Jamaica	10,202	25,507	4,122	10,405
Mexico	353,280	491,830	527,174	679,389
Europe:				
Germany, West	---	---	(2)	110
Spain	116,131	296,054	26,596	72,390
United Kingdom	(2)	187	(2)	923
Africa:				
Tunisia	26,372	55,030	83,967	221,867
United Arab Republic (Egypt)	7,711	18,244	23,636	57,227
Total	[r] 1,516,159	[r] 5,112,173	2,339,877	5,677,162

[r] Revised.

[1] Includes salt brine imports from Canada through the Michigan customs district recorded separately for the first time beginning Sept. 1, 1963; for 1963 (Sept. 1–Dec. 31) 139,289 short tons valued at $37,890, and for 1964, 668,679 short tons valued at $161,670.

[2] Less than ½ unit.

Source: Bureau of the Census.

TABLE 11.—U.S. imports for consumption of salt, by classes

Year	In bags, sacks, barrels, or other packages (dutiable)		Bulk (dutiable) [1]	
	Short tons	Value	Short tons	Value
1955-59 (average)	29,891	$398,784	538,185	$2,769,824
1960	17,693	267,634	1,039,335	4,216,080
1961	9,259	144,210	1,040,825	3,610,434
1962	15,234	253,963	1,358,985	4,843,423
1963	10,166	158,482	[r] 1,505,993	[r] 4,953,691
1964	10,442	157,779	2,329,435	5,519,383

[r] Revised.

[1] Includes salt brine imports from Canada through the Michigan customs district recorded separately for the first time beginning Sept. 1, 1963; for 1963 (Sept. 1-Dec. 31) 139,289 short tons valued at $37,890 and for 1964, 668,679 short tons valued at $161,670.

Source: Bureau of the Census.

TABLE 12.—U.S. imports for consumption of salt, by customs districts [1]

Customs district	1963		1964	
	Short tons	Value	Short tons	Value
Alaska			20	$385
Buffalo	20,488	$112,084	41,431	178,727
Chicago	76,396	345,723	139,780	665,833
Connecticut	41,446	237,034	55,963	274,221
Dakota	7	230		
Duluth and Superior	30,691	161,033	41,757	205,937
Florida			90	405
Georgia	[r] 135,939	523,011	109,813	406,307
Los Angeles	48,513	72,770	80,366	125,051
Maine and New Hampshire	91,009	380,324	98,163	365,897
Maryland	17,554	36,630	105,059	345,198
Massachusetts	121,921	375,133	111,884	370,671
Michigan	[r] 438,649	[r] 1,520,046	888,169	1,244,352
New York	6,083	24,332	30,404	137,280
North Carolina			6,839	16,130
Ohio	80,815	400,522	90,478	379,407
Oregon	54,315	67,900	123,290	151,407
Puerto Rico	11,889	59,445	5,840	29,200
Rhode Island			13,999	68,595
Rochester			6,790	26,559
San Diego	64	1,077	100	1,775
Vermont	10,737	49,916	12,848	56,096
Virginia	31,727	118,025	7,002	26,160
Washington	251,211	357,306	324,147	407,840
Wisconsin	46,705	269,632	45,645	193,729
Total	[r] 1,516,159	[r] 5,112,173	2,339,877	5,677,162

[r] Revised.

[1] Includes salt brine imports from Canada through the Michigan customs district recorded separately for the first time beginning Sept. 1, 1963; for 1963 (Sept. 1-Dec. 31) 139,289 short tons valued at $37,890 and for 1964, 668,679 short tons valued at $161,670.

Source: Bureau of the Census.

TABLE 13.—U.S. exports of salt by countries

Destination	1963		1964	
	Short tons	Value	Short tons	Value
North America:				
Canada	151,756	$1,057,269	196,250	$1,369,625
Central America:				
Costa Rica	191	5,005	619	12,336
Panama	672	9,597	436	10,124
Mexico	3,632	98,244	1,454	48,059
West Indies:				
Bahamas	9,143	54,088	237	20,908
Netherlands Antilles	562	37,330	555	36,538
Other North America	3,249	52,950	2,332	43,274
South America:				
Argentina	788	6,299	2,911	19,649
Chile	868	21,309	756	4,632
Venezuela	5,451	29,132	3,658	26,427
Other South America	979	14,495	1,863	21,237
Europe:				
Greece	3,123	16,418	2,565	20,432
Italy	1,295	13,350	3,456	22,792
Netherlands	1,897	16,189	4,522	23,458
Spain	1,982	19,800	3,773	19,800
Other Europe	3,439	25,073	3,455	19,121
Asia:				
Cambodia	2,296	10,295	49	3,481
Hong Kong	650	5,527	3,249	14,868
Japan	563,255	2,394,836	348,674	1,456,554
Philippines	910	15,395	655	16,362
Saudi Arabia	4,498	42,946	577	43,587
Other Asia	498	14,060	1,517	26,837
Africa:				
Congo (Léopoldville)	5,681	27,427	-------	-------
Nigeria	136	5,441	401	11,820
South Africa, Republic of	3,437	14,935	3,426	26,678
Western Africa, n.e.c	1,840	88,517	-------	-------
Other Africa	1,377	7,487	1,445	9,543
Oceania:				
Australia	6,666	26,665	4,888	28,811
Other Oceania	864	9,945	595	16,274
Total	781,135	4,140,024	594,318	3,373,227

Source: Bureau of the Census.

WORLD REVIEW

Australia.—Salt was discovered in Queensland late in 1964, in a dry hole drilled for oil in the Devonian at 6,413 feet. The salt bed reportedly was 95 percent halite with only minor traces of potassium and had a total thickness of 1,544 feet.

Brazil.—Salt production from solar evaporation plants in the Rio Grande do Norte area, which regularly supply 70 percent of the salt consumed in Brazil, was severely curtailed because of heavy and frequent rains. To alleviate the serious shortage of salt, the Brazilian Salt Institute completed negotiations in December 1964, for importing 88,000 tons of salt, half of which will come from East Germany and half from West Germany.

Canada.—Canadian salt occurrences are listed, developments within the salt industry are outlined, and current Canadian salt operations are described in a recent publication.[2]

Chile.—Wells (Chile) Contratistas Mineros S.A. joined with Cía de Punta de Lobas S.A.M., an existing Chilean salt producer, to form

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[2] Collings, R. K. Salt and the Canadian Salt Industry. Dept. of Mines and Tech. Surveys, Ottawa, Canada, Mines Branch, Inf. Circ. 157, April 1964, 34 pp.

Salchile Ltd., a company that planned to become a major Chilean producer and exporter of high-grade rock salt. The salt deposits to be mined cover an area of approximately 7,000 acres in the northern part of a dry lake bed called Salar Grande, south of Iquique. The thickness of the deposit varies from a few feet to nearly 1,000 feet. The salt will be mined by open pit methods.

Colombia.—Salt production in Colombia, controlled by Concesión de Salines, Bank of the Republic, was to be increased substantially by 1967 to supply local industrial requirements. The $18.8 million caustic soda and soda ash plant at Cartagena, scheduled to begin operating in about 2 years, will eventually consume an estimated 527 tons of salt daily, according to a representative of Concesion de Salinas.

Ecuador.—With the abolishment of the Government salt monopoly in August 1963, about 500 individuals or companies each started producing small quantities of salt. Industrial Salinera Inversionista Dariegas, C.A., reportedly has invested $500,000 for large-scale development of rock salt deposits in the Galapagos Islands. Salinera Ecuatoriana, S.A., obtained financing for a $300,000 solar salt plant at San Pablo, northeast of Salinas on the Santa Elena Peninsula. The Morton Salt Co. in conjunction with a group of Ecuadorian investors was negotiating for land in the Salinas area for the establishment of a mechanized salt plant to cost $1.5 million.

Germany, West.—Salt producing capacity of the Norddeutsche Salinen GmbH, Hanover plant was doubled to 280,000 tons per year. This company was the largest producer of brine springs salt in West Germany and exported nearly 65 percent of its production, mainly to Scandinavian countries for use in the cellulose and chemical industries.

Greece.—A deposit of rock salt with intercalations of anhydrite and other evaporites with a reported total thickness of more than 3,000 feet was discovered by deep-well oil-exploration drilling in the Etoloakarnania region of western Greece. If the deposits prove workable Greek salt needs will be supplied from domestic rock salt sources rather than from solar salt recovery works and foreign imports.

India.—The West Bengal Government decided to form a new company, with 51 percent of the shares government held, to ensure an adequate supply of common salt to Durgapur Chemicals Co., which requires 20,000 tons annually. The plant is to be installed at Contai in the Midnapur district. A previous scheme involving French collaboration has been abandoned.

Nepal.—Nepal Salt Trading Corp. (NSTC) concluded an agreement in late 1963 with State Trading Corp. of India for the purchase of the Nepal annual salt supply of about 60,500 tons at a cost of about $500,000. This was the first purchase negotiated by NSTC, formed by the Nepalese Government in August 1963.

Netherlands.—N.V. Koninklijke Nederlandsche Zoutindustrie announced that it will build a new salt plant at its Hengelo site to be completed by the end of 1965. Evaporation of the pumped brine, storage, and packing the salt will be almost fully automated.

Pakistan.—West Pakistan Industrial Development Corp. announced plans to modernize operations at its six rock salt mining sites in West Pakistan. In addition, the corporation planned to conduct development for salt in the lake areas in the Sind. A detailed report on rock salt mining in Pakistan was published.[3]

Peru.—The Peruvian Government salt monopoly was abolished, but the State-owned Estanco de la Sal was to continue in existence until the supply of salt produced by privately-owned plants became sufficient to meet domestic demand. The Morton Chemical Division of Morton Salt Co., signed a joint venture agreement with Rayon Peruanna, S.A., with an initial investment of $1.3 million, to build a salt processing plant north of the port of Callao using material from salt beds near Lima; processed salt production was expected to start in 1965.

South Africa, Republic of.—The first South African plant for the production of salt by solar evaporation from sea water was placed in operation in midyear by Cerebos (Africa), Ltd., at Coega, near Port Elizabeth.

Yemen.—The most important salt-producing area in Yemen was near the port town of Salif in northwestern Yemen on the Red Sea. About 110,000 tons of rock salt has been mined annually and exported to Japan under the terms of a 5-year contract. Since the termination of this agreement in February 1964, the Salif salt works reportedly have been inactive. A new company, owned 51 percent by the Yemen Arab Republic and 49 percent by the United Arab Republic was being formed to exploit the deposits. No buyer was known to have taken the place of Japan. The Salif works were under the management of the Yemen Arab Republic Ministry of Economics at Sanaa.

TABLE 14.—World production of salt by countries [1] [2]

(Thousand short tons)

Country [1]	1962	1963	1964 [p]
North America:			
Canada	3,665	3,722	3,893
Costa Rica	[e] 10	7	22
El Salvador	20	[e] 20	28
Guatemala	[e] 19	21	[3] 21
Honduras	11	[e] 11	[e] 11
Mexico	1,424	1,350	1,965
Nicaragua	10	18	19
Panama	11	[e] 11	12
United States (sold or used by producers):			
Rock salt	7,726	8,345	8,554
Other salt:			
United States	21,081	22,296	23,069
Puerto Rico	----------	8	5
West Indies:			
British:			
Bahamas	222	283	370
Leeward Islands (exports)	1	(4)	(4)
Turks and Caicos Islands	23	21	15
Cuba	[e] 77	[e] 88	NA
Dominican Republic:			
Rock salt	35	25	[e] 36
Other salt	11	[e] 11	
Haiti	[e] 11	[e] 11	[e] 11
Netherlands Antilles	(4)	(4)	(4)
Total	34,357	36,248	38,031

See footnotes at end of table.

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[3] Bureau of Mines. Mineral Trade Notes. V. 58, No. 2, February 1964, pp. 24–29.

TABLE 14.—World production of salt by countries[1][2]—Continued

(Thousand short tons)

Country[1]	1962	1963	1964[p]
South America:			
Argentina:			
Rock salt	2	1	2
Other salt	543	185	409
Brazil	1,370	1,315	831
Chile	56	53	120
Colombia:			
Rock salt	293	290	319
Other salt	43	37	56
Ecuador	29	[e] 39	[e] 39
Peru	104	96	120
Venezuela	160	84	[e] 220
Total[1]	2,600	2,100	2,120
Europe:			
Austria:			
Rock salt	6	6	1
Other salt	313	374	431
Bulgaria	164	116	[3] 116
Czechoslovakia	201	206	203
France:			
Rock salt and salt from springs	3,285	3,405	3,406
Other salt	1,397	667	[3] 667
Germany:			
East	[e] 2,200	[e] 2,200	[e] 2,200
West (marketable):			
Rock salt	5,027	5,761	5,951
Brine salt	381	399	438
Greece	127	[e] 94	[e] 110
Italy:			
Rock salt and brine salt	1,904	2,142	[3] 2,142
Other salt	1,293	[e] 1,320	[e] 1,320
Malta	2	2	[e] 2
Netherlands	1,391	1,630	1,759
Poland:			
Rock salt	671	711	728
Other salt	1,616	1,638	1,743
Portugal	429	383	[3] 383
Rumania	1,628	1,804	1,994
Spain:			
Rock salt	690	771	[e] 1,870
Other salt[5]	1,118	1,101	
Switzerland	185	211	201
U.S.S.R.[e]	9,400	9,650	9,700
United Kingdom:			
Rock salt	535	842	776
Other salt	6,164	6,317	6,659
Yugoslavia	237	184	203
Total[e][1]	40,360	41,930	43,000
Asia:			
Aden	86	95	89
Afghanistan:			
Rock salt	[e] 24	23	14
Other salt	[e] 72	13	13
Burma	170	177	140
Cambodia	[e] 44	---	---
Ceylon	51	25	64
China[e]	11,000	11,600	12,100
Cyprus	7	8	---
Goa	11	[e] 11	5,122
India:			
Rock salt	6	5,003	
Other salt	4,278		
Indonesia	335	[e] 335	[e] 335
Iran[6]	297	380	[3] 380
Iraq[7]	42	[e] 44	[e] 44
Israel	50	57	[3] 57
Japan	969	876	978
Jordan	21	20	22
Korea:			
North	464	[e] 500	[e] 440
South	428	254	425
Lebanon	[e] 18	21	22
Mongolia	[e] 9	[e] 9	[e] 9

See footnotes at end of table.

TABLE 14.—World production of salt by countries[1,2]—Continued

(Thousand short tons)

Country[1]	1962	1963	1964[p]
Asia—Continued			
Pakistan:			
Rock salt	223	267	217
Other salt	283	234	[e] 358
Philippines	106	77	52
Ryukyu Islands	4	4	[e] 4
Saudi Arabia	----------	11	[3] 11
Syrian Arab Republic	20	17	22
Taiwan	656	690	664
Thailand	165	220	[e] 275
Turkey:			
Rock salt	31	33	36
Other salt	444	406	355
Viet-Nam:			
North	159	141	[e] 165
South	213	141	[3] 141
Yemen	165	[e] 110	[e] 39
Total [e]	20,850	21,800	22,600
Africa:			
Algeria	[e] 144	143	[3] 143
Angola	66	76	89
Cape Verde Islands	30	32	[3] 32
Chad, Republic of (Natron) [e]	28	28	8
Congo, Republic of the (Léopoldville)	1	(4)	(4)
Ethiopia (including Eritrea) [8]	218	281	[e] 290
Ghana	21	----------	34
Kenya	21	36	44
Libya	17	21	14
Malagasy	[e] 19	[e] 19	[e] 19
Mauritius	4	4	4
Morocco	31	41	67
Mozambique	31	[e] 31	[e] 31
Senegal, Republic of (including Mauritania)	53	66	62
Somali Republic	[e] 2	2	7
South Africa, Republic of	281	218	331
South-West Africa:			
Rock salt	4	6	8
Other salt	78	66	104
Sudan	76	41	41
Tanzania	33	37	36
Tunisia	320	331	236
Uganda	3	3	[3] 3
United Arab Republic (Egypt)	617	432	744
Total	2,098	1,914	2,347
Oceania:			
Australia	600	653	[3] 653
New Zealand	10	12	24
Total	610	665	[e] 677
World total (estimate)[1,2]	100,900	104,700	108,800

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[e] Estimate. [p] Preliminary. NA Not available.

[1] Salt is believed to be produced in Albania and Bolivia, data not available. No estimates included in the total.

[2] This table incorporates some revisions. Data do not add exactly to totals shown because of rounding where estimated figures are included in the detail.

[3] 1963 data.

[4] Less than ½ unit.

[5] Includes an average annual production in the Canary Islands of 16,500 short tons of sea-salt.

[6] Year ended Mar. 20 of year following that stated.

[7] Year ended Mar. 31 of year following that stated.

[8] Year ended Sept. 10 of year stated.

TECHNOLOGY

The International Salt Co. Cleveland mine, designed for mass recovery of salt, is reported to be among the newest and most highly mechanized, automated, and flexible mining operations in North

America.[4] The operation is designed for an annual salt-producing capacity of 1.5 to 2 million tons and to handle heavy temporary demands experienced during the Great Lakes navigation season and the winter ice-control season. Underground storage, combined with the hoisting system, is balanced with surface storage facilities and loading stations to permit the movement of 15,000 to 20,000 tons per day of marketable product during these peak demands.

Rock salt production at the mine began in 1962 on an industrial-land area known as Whiskey Island, 1½ miles from downtown Cleveland. This location satisfied the requirements for low-cost water transportation as well as those for available and necessary truck- and rail-transportation facilities. The site was also in the center of a large local market area for industrial salt as well as for highway ice-control salt.

The bed of salt selected for mining at Cleveland is approximately 46 feet thick at depths of 1,741 to 1,787 feet below the surface, but only the middle portion, varying from 14 to 17 feet in thickness, is of sufficient quality for mining. A 5,100-acre reserve, containing over 100 million tons of mineable salt as defined by the exploration program, was obtained from the State of Ohio under a mining lease agreement. The beds mined are reached through two 16-foot-diameter vertical shafts, one for production and the other for service. Mining follows the conventional room and pillar method. The significant feature of the preparation plant—including a crushing-screening operation, thermal-adhesive benefication plant for a part of the crude salt mined, and storage facilities for 36,000 tons of finished product—is that it is entirely underground.

An increased demand for rock salt for deicing roads resulted in an increased activity at the British Isles' only rock salt mine, Meadow Bank, at Winsford, Cheshire, operated by Mond Division of I.C.I. (Imperial Chemical Industries). The pattern of mining the salt bed, 470 feet below ground surface, is the driving of four parallel headings on 100-foot centers, each 50 feet wide and 20 feet high. As the headings are advanced, 50-foot-wide crosscuts are made, again on 100-foot centers, leaving 50- by 50-foot pillars and allowing for a 75 percent recovery of the rock salt.[5]

To meet the steadily growing requirements of salt in the Rumanian chemical industry, it was reported[6] that the conventional underground salt mining methods used in Rumania were superseded by a solution mining process designed by the IPROMIN Institute for Mining Design in Budapest. In the new process, a borehole of 16-inch diameter is drilled by standard techniques to the base of the salt deposit. The borehole is then cased to the salt bed and the casing cemented in to attain a seal. A second casing, 8 inches in diameter, is lowered and a seal made at the lower end between the 8- and 16-inch casings. This space between the casings is filled with insulating fluid (fuel or diesel oil). A third casing, 4 inches in diameter, is set into the salt bed.

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[4] Bleimeister, William C. New Cleveland Mine Was Designed for Mass Recovery of Salt. Eng. and Min. J., v. 165, No. 8, August 1964, pp. 86–93.

[5] Chemistry and Industry (London). I.C.I. Ltd., Rock Salt Mine. June 27, 1964, pp. 1159–1160.

[6] Chemical Trade Journal and Chemical Engineer (London). Automatic Brine Mining. V. 154, No. 4020, June 26, 1964, p. 928.

Water is forced down the annular space between the 4- and 8-inch casings to dissolve the salt and force the brine solution up through the central 4-inch-diameter casing. The Rumania Chamber of Commerce stated that its nation has about 240 proven locations of salt in the 95- to 99-percent NaCl range.

Experimental work indicated that the evaporation process in solar salt production could be controlled more easily, cheaply, and accurately with a filter flame photometer than with the usual density determinations.[7] When a predetermined density value has been reached, further salt cannot be crystallized economically, and the brines are discharged as bitterns. During the crystallization period, changes of the brine density are small, and the density determination method of control using a hydrometer is insensitive. However, while salt is being deposited, the sodium to potassium ratio of brine changes rapidly; this value can be determined with a filter flame photometer and serve as a more sensitive indicator of the useful amount of salt left in the brine. In addition, the flame photometry results are independent of temperature variations and of dilution with rainwater.

Recent experimental results on the degree of ultrafiltration of salts from brine accomplished with bentonite membranes were reported.[8] By combining these results with those of previous work, it was concluded that the requirements for such a mechanism are present in natural environments and may explain subsurface brine concentration.

In solution-mining underground salt and similar minerals, using drilled wells for access, it is desirable to monitor the lateral growth pattern of the resulting fluid-filled cavern so that measures can be taken to maintain operating efficiency. The sonar method of measuring brine cavity shapes, which employs a pulse-echo device lowered into the well, has an insufficient working range for large cavities, and echoes are not returned from highly sloping walls nor from behind rock debris obstructions. Progress in surveying cavities with seismic shear waves, from the surface without interfering with operation of the well, was described.[9] An irregular solution cavity in bedded salt at 500-foot depth was located by this method. Further field work, supported by the Brine Cavity Research Group, an association of 11 chemical and salt-producing companies, is planned to corroborate and extend this work.

Through research and development by one major salt company, a high-purity, very-fine, quick-soluble salt was produced and marketed. It was reported[10] that this material is an effective metal-polish ingredient, dentifrice and dental-plate cleanser, blender in welding and soldering fluxes, baking-dough conditioner, color-standardizing agent in dyes, sweeping and dusting compound ingredient, and a means of improving shampoo and hair-rinse consistencies. The product is made by a process that creates a clinging-flake salt of light irregular crystals that average 99.5 percent sodium chloride. This micronized salt

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[7] Rothbaum, H. P., and W. Kitt. Solar Salt Production Control by Flame Photometry. Chem. and Ind. (London), No. 31, Aug. 1, 1964, p. 1392.

[8] Milne, I. H., J. G. McKelvey, and R. P. Trump. Semi-Permeability of Bentonite Membranes to Brines. Bull. of the Am. Assoc. of Petroleum Geol., v. 48, No. 1, January 1964, pp. 103–105.

[9] Cook, John C. Progress in Mapping Underground Solution Cavities with Seismic Shear Waves. Transl. Soc. Min. Eng., v. 229, No. 1, March 1964, pp. 26–32.

[10] Chemical & Engineering News. Diamond Mills Salt for Highly Soluble Product. V. 42, No. 9, Mar. 2, 1964, p. 57.

(about 40 microns) dissolves five times faster than regular granulated salt, and has a surface area 50 times greater. Its bulk density is 55 pounds per cubic foot, compared with 76 for granulated. The product contains 1.5 percent tricalcium phosphate to assure free flow and to prevent caking. A patent was issued for a process for preparing a similar lightweight, low-bulk density, flake-type salt.[11]

The salt extracting and refining operation of the Cerebos (African) Ltd. at their Coega works along the Cape coast of South Africa between Port Elizabeth and Grahamstown was described.[12] The raw material for the process, containing 3.2 percent dissolved solids of which 2.7 percent is sodium chloride, is pumped from the sea at the rate of nearly 4.5 million gallons per day. The salt is extracted by solar evaporation. A portion of the salt is sold directly from stockpiles but most is refined to produce a high-purity salt for human consumption.

Molten salt chemistry is a subject which is of growing importance in both the academic field and in its technical applications. A new publication [13] reviews some of the relatively new and significant work on fundamental aspects of this field.

Three companies, Shell Oil Co., Earth Energy Inc. (wholly owned subsidiary of The Pure Oil Co.), and Western Geothermal Inc., continued geothermal well drilling in an area southeast of the Salton Sea in the Imperial Valley, Calif. They are also conducting research and development to find an economic method of separating steam from brine while securing maximum returns from both to make power generation and mineral production economically feasible. A method of disposing of the huge waste accumulation from the operation must also be devised. Production from wells is in the form of brine under tremendous pressure that flashes into steam at the surface. It is reported [14] that each of the original six wells drilled also is capable of a daily production of 1,120 tons of NaCl, 324 tons of KCl, 635 tons of $CaCl_2$, and smaller quantities of other salts, if the recovery technologies are solved.

A patent was granted for a process for preparing high-purity salt from natural sodium chloride brines containing calcium sulfate by inhibiting the crystallization of calcium sulfate during the crystallization of salt from an essentially bicarbonate free sodium chloride brine by evaporation and concentration in the presence of starch phosphate.[15]

Several patents were issued for underground solution-mining methods for salt or other soluble mineral salts. In one [16] the well is plugged back to the level of the mineral stratum, the well is cased to the plug, the cavity outside the casing cemented from the plug to ground surface, the cement cut away at a small face of the mineral stratum, and the mineral fractured with pressure applied through the opening in the cement. In another process,[17] in areas containing existing cavities in the salt bed, a new well is drilled at some distance from the base of the cavity and a hydraulic force is applied through the new well to form a crevice in the formation to connect with the cavity. A solvent is then circulated to the cavity and pumped back out the well. In a third patent,[18] the wells are sunk through the mineral bed and into the underlying stratum, the wells enlarged, the interface between the mineral stratum and the base formation weakened horizontally, the interface between those strata opened by application of fluid fracturing pressure, and the dissolving fluid circulated along the interface.

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[11] Ploss, R. S. (assigned to International Salt Co., Clarks Summit, Pa.). Low Bulk Density Chloride and the Process for Preparing Same. U.S. Pat. 3,148,023, Sept. 8, 1964.

[12] South African Mining & Engineering Journal. How E.P. Works Extracts Salt from the Sea. V. 75, Pt. 1, No. 3721, May 29, 1964, pp. 1181–1182.

[13] Molton Salt Chemistry, ed. by Milton Blander. Interscience Publishers, Division of John Wiley & Sons, Inc., New York, 1964, 775 pp.

[14] Engineering and Mining Journal. Salton Sea Geothermal Wells Yield Stream Power and Mineral-rich Brine. V. 165, No. 11, November 1964, p. 116.

[15] Fiedelman, Howard W., and Richlard L. Lintvedt (assigned to Morton Salt Co., Chicago, Ill.). Process for Producing Salt, U.S. Pat. 3,155,458, Nov. 3, 1964.

[16] Jacoby, C. H. (assigned to International Salt Co., Clarks Summit, Pa.). Method of Well Completion. U.S. Pat. Reissue 25,682, Nov. 10, 1964.

A patent was granted for admixing a small percentage of ammonium ferric citrate with granular salt to lessen the tendency for it to cake in moist atmospheres.[19]

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[17] Jacoby, C. H. (assigned to International Salt Co., Clarks Summit, Pa.). Underground Solution Mining of Salt. Canadian Pat. 681,008, Feb. 25, 1964.

[18] Redlinger, J. F. (assigned to FMC Corp., New York). Underground Solution Mining. British Pat. 960,112, June 10, 1964.

[19] Saunders, J. (assigned to A. & R. Scott Ltd., Edinburgh, Scotland). Low-Caking Sodium Chloride Containing Ammonium Ferric Citrate. U.S. Pat. 3,152,863, Oct. 13, 1964.

Sand and Gravel

By William R. Barton[1] and Perry G. Cotter[2]

⁂

SAND and gravel production increased 6 percent in 1964 compared with that of 1963. High demand for sand or gravel was noted in nearly all categories, reflecting the high operating level of construction in the United States. Industrial use of higher-priced sands also gained over a year earlier.

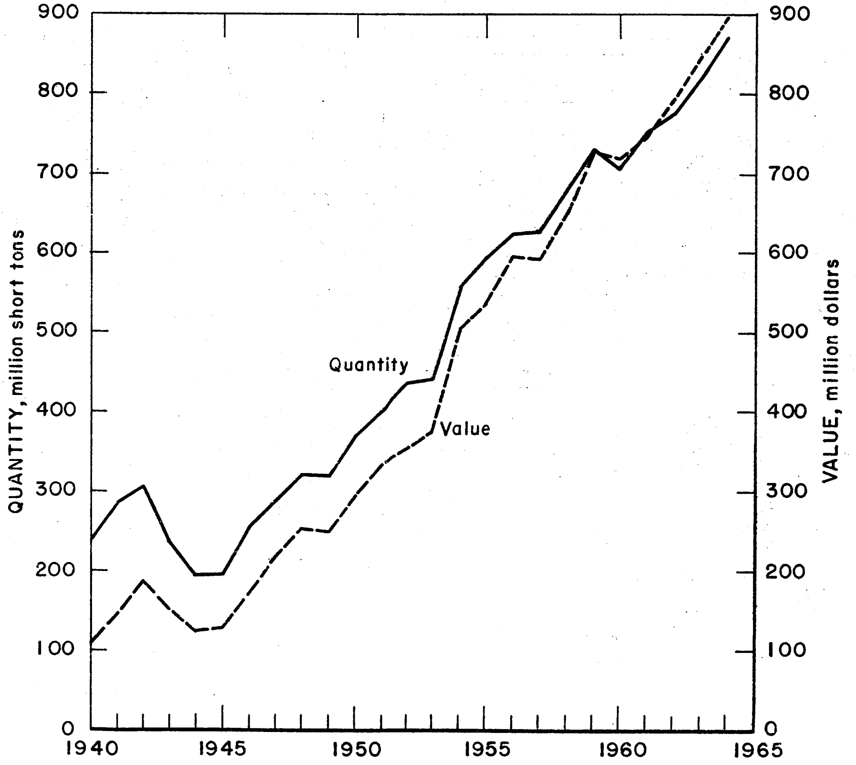

FIGURE 1.—Production and value of sand and gravel in the United States.

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[1] Commodity specialist, Division of Minerals.
[2] Former commodity specialist, Division of Minerals (now retired).

LEGISLATION AND GOVERNMENT PROGRAMS

Apportionment of $3,800 million Federal aid to the States for roadbuilding in Fiscal Year 1966 was announced. The Interstate System was allotted $2,800 million, and $1,000 million was allocated for Federal aid to primary and secondary highway systems and their urban extensions.

Bills presented to the 88th Congress to clarify the meaning of the term "common varieties," when applied to sand and gravel deposits on public lands, were not acted upon.

TABLE 1.—Sand and gravel sold or used by producers in the United States, by classes of operations and uses

(Thousand short tons and thousand dollars)

Classes of operation and use	1963		1964	
	Quantity	Value	Quantity	Value
Construction:				
Building:				
Sand	140,352	$145,362	144,045	$148,821
Gravel	118,357	149,870	120,274	153,703
Paving:				
Sand	113,346	102,169	119,930	110,797
Gravel	326,437	308,031	345,029	331,696
Fill:				
Sand	32,248	17,037	30,575	16,896
Gravel	47,563	34,463	61,267	33,602
Railroad ballast:				
Sand	444	344	379	291
Gravel	3,509	2,898	3,544	2,838
Other:				
Sand	6,489	5,022	8,429	6,989
Gravel	5,361	6,237	6,194	7,398
Total construction	794,106	771,433	839,666	813,031
Industrial sand:				
Unground:				
Glass	7,204	23,626	7,638	24,414
Molding	7,579	20,814	8,988	24,240
Grinding and polishing	[r] 1,065	[r] 2,084	989	1,798
Blast sand	[r] 829	[r] 3,776	1,087	4,517
Fire or furnace	568	1,082	584	1,190
Engine	838	1,659	869	1,780
Filtration	297	756	163	438
Oil hydrafrac	[r] 282	[r] 2,015	384	2,219
Other	1,396	3,833	1,395	3,577
Total unground	[r] 20,058	[r] 59,645	22,097	64,173
Ground [1]	1,041	8,921	1,186	10,162
Total industrial	[r] 21,099	[r] 68,566	23,283	74,335
Miscellaneous gravel	6,645	7,273	5,830	6,726
Grand total	[r] 821,850	[r] 847,272	868,779	894,092
Commercial:				
Sand	[r] 271,456	[r] 309,986	283,283	325,912
Gravel	[r] 319,215	[r] 350,010	338,109	374,139
Government-and-contractor: [2]				
Sand	[r] 42,522	[r] 28,514	43,358	32,217
Gravel	[r] 188,657	[r] 158,762	204,029	161,824

[r] Revised.

[1] See table 10 for use breakdown; any difference between the total and the detailed figures is due to rounding.

[2] Approximate figures for operations by States, counties, municipalities, and other Government agencies under lease.

TABLE 2.—Sand and gravel sold or used by producers in the United States[1]

(Thousand short tons and thousand dollars)

Year	Sand		Gravel		Total	
	Quantity	Value	Quantity	Value	Quantity	Value
1955–59 (average)	240,634	$250,552	412,487	$372,184	653,121	$622,736
1960	265,656	293,599	444,136	426,833	709,792	720,432
1961	283,336	303,549	468,448	447,752	751,784	751,301
1962	299,757	328,563	476,944	466,162	776,701	794,725
1963[r]	313,978	338,500	507,872	508,772	821,850	847,272
1964	326,641	358,129	542,138	535,963	868,779	894,092

[r] Revised.

[1] Inludes possessions and other areas administered by the United States (1955–56).

DOMESTIC PRODUCTION

The 1964 output of 868.8 million tons of sand and gravel valued at $894.1 million represented an increase of 6 percent in tonnage and 6 percent in value over that of 1963. California's production of 113 million tons made it the leading producer State followed, in order of rank, by: Michigan, New York, Ohio, and Minnesota. The sand and gravel produced in these 5 leading States represented 32 percent of the total U.S. production.

Seventy-two percent of the total sand and gravel production was furnished by commercial operators, the same as in 1963.

The quantity of sand and gravel reported under Government-and-contractor production continued to increase, up 8 percent from that of 1963. Sand and gravel for paving and gravel for fill continued as the most important Government-and-contractor categories.

In 1964, 85 percent of sand and gravel was reported as processed the same as in 1963. The degree of processing was not specified, but the trend in recent years has been toward more complex treatment to meet more demanding specifications.

TABLE 3.—Sand and gravel sold or used by producers in the United States, by States, and classes of operations [1]

(Thousand short tons and thousand dollars)

State	1963						1964					
	Commercial		Government-and-contractor		Total		Commercial		Government-and-contractor		Total	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
Alabama	5, 079	$5, 610	283	$168	5, 362	$5, 778	5, 650	$6, 120	190	$71	5, 840	$6, 191
Alaska	614	1, 573	16, 310	20, 433	16, 924	22, 006	4, 401	4, 121	21, 688	14, 367	26, 089	18, 488
Arizona	8, 119	8, 733	6, 918	5, 735	15, 037	14, 468	10, 244	12, 138	7, 872	8, 730	18, 116	20, 868
Arkansas	7, 699	9, 096	4, 400	4, 493	12, 099	13, 589	8, 637	10, 990	3, 157	3, 846	11, 794	14, 836
California	93, 835	110, 055	18, 353	18, 120	112, 188	128, 175	96, 871	113, 337	16, 124	15, 996	112, 995	129, 333
Colorado	11, 218	12, 365	9, 167	8, 561	20, 385	20, 926	9, 006	10, 809	11, 740	11, 418	20, 746	22, 227
Connecticut	7, 632	8, 065	2, 872	1, 277	10, 504	9, 342	7, 377	8, 375	2, 711	1, 062	10, 088	9, 437
Delaware	1, 095	1, 136	----------	----------	1, 095	1, 136	1, 282	1, 280	----------	----------	1, 282	1, 280
Florida	7, 258	5, 578	284	244	7, 542	5, 822	6, 911	6, 039	509	388	7, 420	6, 427
Georgia	3, 817	3, 922	----------	----------	3, 817	3, 922	4, 159	4, 311	----------	----------	4, 159	4, 311
Hawaii	304	763	----------	----------	304	763	400	971	7	8	407	979
Idaho	1, 723	2, 188	10, 709	8, 426	12, 432	10, 614	2, 871	3, 111	6, 711	5, 580	9, 582	8, 691
Illinois	30, 061	35, 369	1, 689	1, 063	31, 750	36, 432	33, 469	39, 094	1, 411	872	34, 880	39, 966
Indiana	22, 147	20, 298	694	384	22, 841	20, 682	23, 683	21, 400	733	411	24, 416	21, 811
Iowa	11, 272	11, 095	2, 896	1, 750	14, 168	12, 845	12, 112	12, 551	1, 778	995	13, 890	13, 546
Kansas	9, 763	7, 603	2, 299	1, 073	12, 062	8, 676	10, 227	7, 788	2, 741	1, 320	12, 968	9, 108
Kentucky	6, 273	5, 961	206	110	6, 479	6, 071	6, 184	6, 040	376	257	6, 560	6, 297
Louisiana	12, 125	14, 551	375	150	12, 500	14, 701	13, 228	14, 959	366	294	13, 594	15, 253
Maine	2, 000	1, 463	9, 196	3, 210	11, 196	4, 673	2, 276	1, 636	11, 276	4, 827	13, 552	6, 463
Maryland	13, 109	15, 991	200	70	13, 309	16, 061	14, 531	17, 932	510	139	15, 041	18, 071
Massachusetts	16, 015	14, 347	3, 890	1, 248	19, 905	15, 595	14, 782	14, 781	6, 559	2, 013	21, 341	16, 794
Michigan	37, 996	35, 660	12, 463	7, 770	50, 459	43, 430	40, 577	38, 164	11, 344	6, 241	51, 921	44, 405
Minnesota	19, 769	16, 952	10, 691	6, 366	30, 460	23, 318	22, 937	18, 220	12, 880	7, 687	35, 817	25, 907
Mississippi	6, 306	6, 266	519	790	6, 825	7, 056	7, 479	7, 871	346	698	7, 825	8, 569
Missouri	9, 808	11, 580	845	680	10, 653	12, 260	10, 761	12, 762	722	618	11, 483	13, 380
Montana	2, 873	3, 018	11, 447	10, 737	14, 320	13, 755	2, 764	2, 883	13, 253	14, 957	16, 017	17, 840
Nebraska	9, 895	9, 481	1, 272	1. 201	11, 167	10, 682	10, 234	11, 416	4, 407	4, 332	14, 641	15, 748
Nevada	3, 546	5, 675	6, 142	4, 837	9, 688	10, 512	4, 790	7, 018	9, 352	7, 409	14, 142	14, 427
New Hampshire	3, 203	2, 844	4, 380	1, 533	7, 583	4, 377	2, 883	2, 925	5, 885	2, 071	8, 768	4, 996
New Jersey	16, 664	25, 241	8	4	16, 672	25, 245	17, 658	27, 077	3	2	17, 661	27, 079
New Mexico	4, 174	5, 194	4, 229	7, 650	8, 403	12, 844	4, 660	6, 000	4, 121	4, 160	8, 781	10, 160
New York	27, 849	30, 107	9, 530	7, 172	37. 379	37, 279	26, 611	28, 792	12, 671	9, 791	39, 282	38, 583
North Carolina	7, 646	8, 064	3, 379	2, 069	11, 025	10, 133	7, 413	8, 119	3, 737	2, 285	11, 150	10, 404
North Dakota	2, 771	3, 036	6, 760	6, 157	9, 531	9, 193	2, 840	3, 280	7, 680	6, 862	10, 520	10, 142
Ohio	36, 812	43, 726	978	642	37, 790	44, 368	37, 521	45, 475	250	92	37, 771	45, 567
Oklahoma	4, 644	5, 756	776	360	5, 420	6, 116	5, 032	6, 031	1, 648	972	6, 680	7, 003
Oregon	8, 929	11, 026	6, 786	7, 824	15, 715	18, 850	9, 355	11, 660	8, 898	13, 498	18, 253	25, 158
Pennsylvania	13, 989	23, 487	77	51	14, 066	23, 538	16, 169	26, 357	30	57	16, 199	26, 414

Rhode Island	1, 747	1, 835	3	5	1, 750	1, 840	1, 647	1, 613	------------	------------	1, 647	1, 613
South Carolina	4, 024	4, 737	27	14	4, 051	4, 751	4, 622	5, 262	------------	------------	4, 622	5, 262
South Dakota	3, 499	3, 320	17, 308	12, 995	20, 807	16, 315	2, 559	2, 474	11, 211	11, 167	13, 770	13, 641
Tennessee	6, 956	8, 863	657	580	7, 613	9, 443	7, 222	9, 631	750	614	7, 972	10, 245
Texas	27, 511	32, 085	5, 745	4, 226	33, 256	36, 311	25, 249	30, 896	3, 906	2, 498	29, 155	33, 394
Utah	5, 779	5, 062	5, 931	5, 349	11, 710	10, 411	5, 899	6, 338	4, 319	4, 067	10, 218	10, 405
Vermont	1, 090	943	1, 284	466	2, 374	1, 409	1, 210	1, 312	554	182	1, 764	1, 494
Virginia	10, 177	17, 494	222	260	10, 399	17, 754	10, 334	13, 467	254	255	10, 588	13, 722
Washington	12, 399	12, 484	10, 364	8, 004	22, 763	20, 488	14, 637	15, 015	17, 283	10, 956	31, 920	25, 971
West Virginia	4, 808	10, 579	------------	------------	4, 808	10, 579	5, 472	11, 555	------------	------------	5, 472	11, 555
Wisconsin	[r] 22, 476	[r] 17, 595	12, 887	7, 268	[r] 35, 363	[r] 24, 863	22, 378	18, 174	11, 970	6, 521	34, 348	24, 695
Wyoming	2, 173	2, 124	5, 728	5, 751	7, 901	7, 875	2, 178	2, 481	3, 454	3, 455	5, 632	5, 936
Total	[r] 590, 671	[r] 659, 996	231, 179	187, 276	[r] 821, 850	[r] 847, 272	621, 392	700, 051	247, 387	194, 041	868, 779	894, 092
American Samoa	------------	------------	77	193	77	193	------------	------------	22	20	22	20
Panama Canal Zone	84	87	------------	------------	84	87	84	82	------------	------------	84	82
Puerto Rico	6, 832	9, 743	784	664	7, 616	10, 407	7, 001	10, 697	815	795	7, 816	11, 492

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[r] Revised.

[1] Data shown in the State chapters of volume III may vary slightly due to rounding.

TABLE 4.—Sand and gravel sold or used by producers in the United States in 1964, by States, uses and classes of operations.

(Commercial unless otherwise indicated)

State	Sand, construction							
	Building				Paving			
	Commercial		Government-and-contractor		Commercial		Government-and-contractor	
	Short tons	Value	Short tons	Value	Short tons	Value	Short tons	Value
Alabama	1, 820, 000	$1, 703, 000	--------	--------	898, 000	$888, 000	107, 000	$40, 000
Alaska	143, 000	447, 000	70, 000	$363, 000	W	W	83, 000	178, 000
Arizona	1, 782, 000	2, 346, 000	--------	--------	782, 000	912, 000	1, 167, 000	1, 373, 000
Arkansas	1, 676, 000	1, 857, 000	--------	--------	1, 414, 000	1, 369, 000	1, 442, 000	1, 226, 000
California	21, 994, 000	24, 542, 000	197, 000	285, 000	11, 896, 000	12, 799, 000	5, 000, 000	5, 854, 000
Colorado	1, 960, 000	2, 260, 000	3, 000	3, 000	618, 000	764, 000	1, 503, 000	1, 500, 000
Connecticut	2, 106, 000	2, 484, 000	--------	--------	1, 255, 000	1, 268, 000	112, 000	43, 000
Delaware	292, 000	328, 000	--------	--------	200, 000	189, 000	--------	--------
Florida	5, 587, 000	4, 369, 000	60, 000	44, 000	310, 000	268, 000	437, 000	320, 000
Georgia	2, 634, 000	1, 998, 000	--------	--------	273, 000	233, 000	--------	--------
Hawaii	328, 000	818, 000	--------	--------	28, 000	69, 000	5, 000	6, 000
Idaho	245, 000	481, 000	16, 000	9, 000	58, 000	67, 000	74, 000	53, 000
Illinois	6, 527, 000	5, 850, 000	2, 000	1, 000	5, 550, 000	5, 084, 000	325, 000	177, 000
Indiana	4, 553, 000	3, 847, 000	--------	--------	4, 932, 000	3, 642, 000	22, 000	10, 000
Iowa	2, 094, 000	2, 005, 000	--------	--------	2, 394, 000	2, 308, 000	116, 000	66, 000
Kansas	3, 645, 000	2, 736, 000	17, 000	7, 000	3, 350, 000	2, 638, 000	1, 258, 000	637, 000
Kentucky	1, 972, 000	2, 044, 000	--------	--------	1, 962, 000	1, 726, 000	--------	--------
Louisiana	2, 613, 000	2, 426, 000	--------	--------	1, 843, 000	1, 562, 000	8, 000	9, 000
Maine	310, 000	255, 000	--------	--------	229, 000	187, 000	908, 000	672, 000
Maryland	3, 149, 000	4, 271, 000	--------	--------	1, 969, 000	2, 916, 000	2, 000	1, 000
Massachusetts	3, 371, 000	3, 274, 000	--------	--------	2, 242, 000	1, 972, 000	23, 000	13, 000
Michigan	5, 754, 000	4, 169, 000	107, 000	48, 000	5, 135, 000	4, 274, 000	1, 659, 000	744, 000
Minnesota	3, 488, 000	2, 697, 000	--------	--------	2, 165, 000	1, 318, 000	2, 535, 000	1, 381, 000
Mississippi	1, 015, 000	863, 000	--------	--------	1, 109, 000	958, 000	153, 000	294, 000
Missouri	3, 622, 000	3, 243, 000	--------	--------	1, 213, 000	1, 172, 000	43, 000	49, 000
Montana	300, 000	445, 000	313, 000	402, 000	100, 000	128, 000	321, 000	378, 000
Nebraska	2, 407, 000	2, 492, 000	--------	--------	1, 333, 000	1, 410, 000	1, 840, 000	1, 822, 000
Nevada	807, 000	1, 354, 000	13, 000	13, 000	74, 000	207, 000	230, 000	134, 000
New Hampshire	561, 000	437, 000	--------	--------	565, 000	469, 000	2, 319, 000	815, 000
New Jersey	5, 013, 000	5, 173, 000	--------	--------	2, 756, 000	2, 439, 000	1, 000	1, 000
New Mexico	1, 024, 000	1, 223, 000	20, 000	19, 000	210, 000	269, 000	21, 000	12, 000
New York	8, 820, 000	9, 947, 000	78, 000	135, 000	4, 886, 000	5, 003, 000	579, 000	394, 000
North Carolina	2, 311, 000	1, 865, 000	--------	--------	1, 128, 000	927, 000	1, 884, 000	957, 000
North Dakota	375, 000	507, 000	--------	--------	225, 000	260, 000	3, 074, 000	2, 503, 000
Ohio	6, 419, 000	6, 915, 000	--------	--------	7, 651, 000	7, 774, 000	--------	--------

Oklahoma	2, 418, 000	2, 185, 000	------	------	843, 000	777, 000	171, 000	218, 000
Oregon	1, 204, 000	1, 774, 000	1, 000	2, 000	409, 000	553, 000	264, 000	436, 000
Pennsylvania	4, 697, 000	6, 648, 000	------	------	2, 859, 000	4, 109, 000	------	------
Rhode Island	391, 000	445, 000	------	------	149, 000	122, 000	------	------
South Carolina	2, 015, 000	1, 221, 000	------	------	823, 000	380, 000	------	------
South Dakota	381, 000	395, 000	12, 000	12, 000	301, 000	293, 000	2, 423, 000	2, 423, 000
Tennessee	1, 922, 000	2, 858, 000	------	------	1, 085, 000	1, 560, 000	11, 000	16, 000
Texas	8, 645, 000	8, 650, 000	1, 000	2, 000	2, 423, 000	2, 639, 000	411, 000	173, 000
Utah	1, 265, 000	1, 428, 000	9, 000	10, 000	488, 000	529, 000	191, 000	142, 000
Vermont	139, 000	125, 000	------	------	187, 000	142, 000	67, 000	19, 000
Virginia	2, 002, 000	2, 608, 000	------	------	1, 975, 000	2, 036, 000	104, 000	36, 000
Washington	2, 170, 000	2, 556, 000	31, 000	46, 000	W	W	449, 000	372, 000
West Virginia	1, 446, 000	1, 807, 000	------	------	601, 000	931, 000	------	------
Wisconsin	3, 481, 000	2, 783, 000	------	------	1, 689, 000	1, 214, 000	2, 903, 000	1, 485, 000
Wyoming	202, 000	266, 000	------	------	141, 000	184, 000	17, 000	17, 000
Undistributed	------	------	------	------	942, 000	860, 000	------	------
Total	143, 095, 000	147, 420, 000	950, 000	1, 401, 000	85, 668, 000	83, 798, 000	34, 262, 000	26, 999, 000
American Samoa	------	------	22, 000	20, 000	------	------	------	------
Panama Canal Zone	------	------	------	------	------	------	------	------
Puerto Rico	2, 012, 000	3, 456, 000	------	------	1, 539, 000	1, 904, 000	201, 000	256, 000

W Withheld to avoid disclosing individual company confidential data; included with "Undistributed."

TABLE 4.—Sand and gravel sold or used by producers in the United States in 1964, by States, uses and classes of operations—Continued

(Commercial unless otherwise indicated)

State	Sand, construction—Continued									
	Railroad ballast		Fill				Other [1]			
			Commercial		Government-and-contractor		Commercial		Government-and-contractor	
	Short tons	Value	Short tons	Value	Short tons	Value	Short tons	Value	Short tons	Value
Alabama	11,000	$5,000	100,000	$85,000	----------	----------	----------	----------	----------	----------
Alaska	----------	----------	183,000	364,000	5,000	$2,000	W	W	----------	----------
Arizona	----------	----------	190,000	94,000	64,000	49,000	W	W	----------	----------
Arkansas	----------	----------	W	W	----------	----------	W	W	----------	----------
California	63,000	47,000	3,534,000	2,734,000	549,000	441,000	578,000	$551,000	4,000	$5,000
Colorado	----------	----------	118,000	61,000	3,000	3,000	W	W	----------	----------
Connecticut	----------	----------	243,000	100,000	W	W	W	W	W	W
Delaware	----------	----------	W	W	----------	----------	----------	----------	----------	----------
Florida	----------	----------	335,000	170,000	----------	----------	81,000	55,000	----------	----------
Georgia	W	W	55,000	32,000	----------	----------	----------	----------	----------	----------
Hawaii	----------	----------	----------	----------	----------	----------	----------	----------	2,000	2,000
Idaho	W	W	W	W	375,000	270,000	W	W	----------	----------
Illinois	W	W	W	W	----------	----------	26,000	17,000	----------	----------
Indiana	W	W	1,568,000	711,000	----------	----------	77,000	54,000	----------	----------
Iowa	W	W	743,000	412,000	25,000	18,000	W	W	1,000	1,000
Kansas	42,000	25,000	901,000	390,000	----------	----------	118,000	100,000	63,000	25,000
Kentucky	----------	----------	616,000	376,000	----------	----------	----------	----------	----------	----------
Louisiana	----------	----------	15,000	15,000	----------	----------	118,000	95,000	----------	----------
Maine	----------	----------	199,000	83,000	3,000	1,000	72,000	50,000	203,000	158,000
Maryland	----------	----------	891,000	332,000	W	W	830,000	730,000	W	W
Massachusetts	----------	----------	421,000	163,000	1,000	1,000	W	W	17,000	20,000
Michigan	W	W	3,204,000	1,412,000	1,215,000	394,000	W	W	127,000	58,000
Minnesota	24,000	15,000	564,000	247,000	158,000	54,000	66,000	49,000	14,000	5,000
Mississippi	----------	----------	W	W	10,000	7,000	W	W	----------	----------
Missouri	3,000	2,000	421,000	371,000	----------	----------	W	W	----------	----------
Montana	----------	----------	48,000	37,000	1,000	1,000	21,000	19,000	----------	----------
Nebraska	----------	----------	455,000	416,000	----------	----------	----------	----------	----------	----------
Nevada	W	W	32,000	28,000	----------	----------	W	W	16,000	11,000
New Hampshire	----------	----------	71,000	23,000	180,000	63,000	W	W	----------	----------
New Jersey	----------	----------	1,074,000	478,000	----------	----------	772,000	798,000	2,000	1,000
New Mexico	----------	----------	W	W	101,000	87,000	----------	----------	----------	----------
New York	----------	----------	859,000	383,000	2,459,000	1,025,000	1,467,000	928,000	439,000	181,000
North Carolina	W	W	110,000	70,000	343,000	223,000	24,000	21,000	636,000	274,000

North Dakota	------------	------------	52,000	52,000	------------	------------	------------	------------	------------	------------
Ohio	------------	------------	752,000	563,000	------------	------------	151,000	134,000	------------	------------
Oklahoma	------------	------------	368,000	211,000	91,000	32,000	------------	------------	------------	------------
Oregon	------------	------------	284,000	271,000	------------	------------	28,000	30,000	------------	------------
Pennsylvania	------------	------------	24,000	25,000	------------	------------	477,000	752,000	26,000	33,000
Rhode Island	------------	------------	27,000	14,000	------------	------------	W	W	------------	------------
South Carolina	------------	------------	39,000	25,000	------------	------------	------------	------------	------------	------------
South Dakota	------------	------------	20,000	16,000	------------	------------	35,000	35,000	------------	------------
Tennessee	------------	------------	W	W	------------	------------	W	W	------------	------------
Texas	------------	------------	817,000	384,000	11,000	4,000	W	W	------------	------------
Utah	------------	------------	91,000	49,000	84,000	42,000	15,000	23,000	------------	------------
Vermont	------------	------------	51,000	19,000	------------	------------	52,000	57,000	33,000	12,000
Virginia	W	W	927,000	533,000	------------	------------	W	W	29,000	12,000
Washington	70,000	84,000	830,000	573,000	11,000	9,000	49,000	50,000	1,000	1,000
West Virginia	11,000	17,000	W	W	------------	------------	------------	------------	------------	------------
Wisconsin	W	W	1,115,000	572,000	564,000	186,000	21,000	15,000	174,000	73,000
Wyoming	------------	------------	4,000	4,000	6,000	3,000	------------	------------	7,000	4,000
Undistributed	155,000	96,000	1,889,000	1,063,000	76,000	20,000	1,540,000	1,544,000	17,000	6,000
Total	379,000	291,000	24,240,000	13,961,000	6,335,000	2,935,000	6,618,000	6,107,000	1,811,000	882,000
American Somoa	------------	------------	------------	------------	------------	------------	------------	------------	------------	------------
Panama Canal Zone	------------	------------	------------	------------	------------	------------	84,000	82,000	------------	------------
Puerto Rico	------------	------------	500,000	453,000	472,000	409,000	------------	------------	------------	------------

W Withheld to avoid disclosing individual company confidential data; included with "Undistributed."

[1] Includes unspecified.

TABLE 4.—Sand and gravel sold or used by producers in the United States in 1964, by States, uses and classes of operations—Continued

(Commercial unless otherwise indicated)

State	Sand, industrial									
	Glass		Molding		Grinding and polishing		Blast		Fire or furnace	
	Short tons	Value	Short tons	Value	Short tons	Value	Short tons	Value	Short tons	Value
Alabama	------	------	W	W	------	------	------	------	------	------
Alaska	------	------	------	------	------	------	------	------	------	------
Arizona	------	------	------	------	------	------	W	W	------	------
Arkansas	W	W	W	W	------	------	W	W	------	------
California	833,000	$3,924,000	57,000	$271,000	------	------	260,000	$954,000	W	W
Colorado	------	------	------	------	------	------	2,000	7,000	------	------
Connecticut	------	------	W	W	W	W	------	------	------	------
Delaware	------	------	------	------	------	------	------	------	------	------
Florida	W	W	------	------	------	------	W	W	------	------
Georgia	W	W	W	W	------	------	W	W	------	------
Hawaii	------	------	------	------	------	------	10,000	22,000	------	------
Idaho	5,000	26,000	------	------	------	------	------	------	------	------
Illinois	1,609,000	3,295,000	975,000	3,115,000	W	W	W	W	------	------
Indiana	W	W	W	W	------	------	------	------	W	W
Iowa	------	------	W	W	------	------	W	W	------	------
Kansas	------	------	------	------	------	------	W	W	------	------
Kentucky	------	------	W	W	------	------	------	------	------	------
Louisiana	------	------	------	------	------	------	W	W	------	------
Maine	------	------	------	------	------	------	------	------	------	------
Maryland	W	W	------	------	------	------	------	------	------	------
Massachusetts	------	------	W	W	------	------	5,000	55,000	------	------
Michigan	W	W	2,819,000	5,085,000	W	W	------	------	------	------
Minnesota	W	W	W	W	W	W	W	W	------	------
Mississippi	------	------	W	W	------	------	W	W	------	------
Missouri	469,000	1,166,000	100,000	256,000	W	W	W	W	------	------
Montana	------	------	------	------	------	------	------	------	------	------
Nebraska	------	------	------	------	------	------	------	------	------	------
Nevada	W	W	W	W	------	------	------	------	W	W
New Hampshire	------	------	------	------	------	------	------	------	------	------
New Jersey	773,000	2,901,000	1,672,000	5,262,000	------	------	139,000	649,000	W	W
New Mexico	------	------	------	------	------	------	------	------	------	------
New York	------	------	W	W	------	------	------	------	------	------
North Carolina	------	------	------	------	------	------	W	W	------	------
North Dakota	------	------	------	------	------	------	------	------	------	------
Ohio	W	W	507,000	2,052,000	W	W	W	W	W	W
Oklahoma	W	W	W	W	------	------	W	W	------	------
Oregon	------	------	1,000	6,000	------	------	------	------	------	------

Pennsylvania	W	W	124,000	396,000	W	W	W	W	108,000	$326,000
Rhode Island	------	------	W	W	------	------	------	------	------	------
South Carolina	W	W	W	W	------	------	9,000	41,000	W	W
South Dakota	------	------	------	------	------	------	------	------	------	------
Tennessee	W	W	285,000	853,000	W	W	------	------	20,000	40,000
Texas	W	W	34,000	81,000	------	------	W	W	2,000	4,000
Utah	------	------	4,000	12,000	------	------	(1)	1,000	W	W
Vermont	------	------	------	------	------	------	------	------	------	------
Virginia	W	W	------	------	------	------	------	------	------	------
Washington	W	W	W	W	------	------	W	W	------	------
West Virginia	W	W	W	W	------	------	W	W	61,000	70,000
Wisconsin	W	W	833,000	2,125,000	------	------	23,000	85,000	------	------
Wyoming	------	------	------	------	------	------	------	------	------	------
Undistributed	3,949,000	13,102,000	1,577,000	4,726,000	989,000	$1,798,000	639,000	2,703,000	393,000	750,000
Total	7,638,000	24,414,000	8,988,000	24,240,000	989,000	1,798,000	1,087,000	4,517,000	584,000	1,190,000
American Samoa	------	------	------	------	------	------	------	------	------	------
Panama Canal Zone	------	------	------	------	------	------	------	------	------	------
Puerto Rico	25,000	35,000	------	------	------	------	------	------	------	------

W Withheld to avoid disclosing individual company confidential data; included with "Undistributed."

[1] Less than ½ unit.

TABLE 4.—Sand and gravel sold or used by producers in the United States in 1964, by States, uses and classes of operations—Continued

(Commercial unless otherwise indicated)

State	Sand, industrial—Continued									
	Engine		Filtration		Oil (hydrafrac)		Other		Ground sand	
	Short tons	Value	Short tons	Value	Short tons	Value	Short tons	Value	Short tons	Value
Alabama	W	W	--	--	--	--	--	--	--	--
Alaska	--	--	--	--	--	--	--	--	--	--
Arizona	--	--	--	--	16,000	$171,000	--	--	--	--
Arkansas	--	--	--	--	--	--	W	W	W	W
California	56,000	$163,000	29,000	$101,000	W	W	48,000	$205,000	98,000	$351,000
Colorado	--	--	1,000	4,000	--	--	--	--	1,000	3,000
Connecticut	--	--	W	W	--	--	--	--	--	--
Delaware	W	W	--	--	--	--	--	--	--	--
Florida	--	--	W	W	--	--	W	W	--	--
Georgia	--	--	W	W	--	--	W	W	W	W
Hawaii	--	--	--	--	--	--	4,000	7,000	--	--
Idaho	--	--	--	--	--	--	--	--	--	--
Illinois	W	W	W	W	W	W	W	W	202,000	2,224,000
Indiana	W	W	--	--	--	--	W	W	W	W
Iowa	--	--	--	--	--	--	--	--	--	--
Kansas	27,000	40,000	W	W	W	W	2,000	2,000	--	--
Kentucky	--	--	--	--	--	--	W	W	--	--
Louisiana	--	--	--	--	--	--	--	--	W	W
Maine	2,000	2,000	--	--	--	--	1,000	1,000	--	--
Maryland	--	--	--	--	--	--	--	--	--	--
Massachusetts	--	--	9,000	15,000	--	--	1,000	6,000	--	--
Michigan	W	W	--	--	--	--	W	W	W	W
Minnesota	W	W	--	--	W	W	--	--	W	W
Mississippi	--	--	--	--	--	--	--	--	--	--
Missouri	W	W	W	W	--	--	W	W	W	W
Montana	--	--	--	--	--	--	--	--	--	--
Nebraska	--	--	--	--	--	--	--	--	--	--
Nevada	--	--	--	--	--	--	W	W	--	--
New Hampshire	W	W	--	--	--	--	--	--	--	--
New Jersey	W	W	W	W	--	--	147,000	628,000	W	W
New Mexico	W	W	--	--	--	--	--	--	--	--
New York	24,000	42,000	W	W	--	--	W	W	--	--
North Carolina	--	--	W	W	--	--	3,000	3,000	--	--
North Dakota	--	--	--	--	--	--	--	--	--	--
Ohio	W	W	14,000	47,000	--	--	166,000	369,000	W	W
Oklahoma	--	--	W	W	--	--	W	W	W	W
Oregon	W	W	--	--	--	--	--	--	--	--

Pennsylvania	W	W	----------	----------	----------	----------	283,000	566,000	W	W
Rhode Island	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------
South Carolina	W	W	W	W	----------	----------	24,000	59,000	52,000	415,000
South Dakota	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------
Tennessee	2,000	3,000	----------	----------	----------	----------	W	W	----------	----------
Texas	17,000	46,000	W	W	W	W	W	W	18,000	68,000
Utah	6,000	14,000	----------	----------	----------	----------	5,000	17,000	----------	----------
Vermont	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------
Virginia	79,000	128,000	W	W	----------	----------	W	W	W	W
Washington	----------	----------	----------	----------	----------	----------	(1)	1,000	2,000	17,000
West Virginia	W	W	----------	----------	----------	----------	W	W	W	W
Wisconsin	25,000	21,000	W	W	14,000	69,000	6,000	40,000	W	W
Wyoming	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------
Undistributed	631,000	1,321,000	110,000	271,000	354,000	1,979,000	705,000	1,673,000	813,000	7,084,000
Total	869,000	1,780,000	163,000	438,000	384,000	2,219,000	1,395,000	3,577,000	1,186,000	10,162,000
American Samoa	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------
Panama Canal Zone	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------
Puerto Rico	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------

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W Withheld to avoid disclosing individual company confidential data; included with "Undistributed."

[1] Less than ½ unit.

TABLE 4.—Sand and gravel sold or used by producers in the United States in 1964, by States, uses and classes of operations—Continued

(Commercial unless otherwise indicated)

State	Gravel, construction							
	Building				Paving			
	Commercial		Government-and-contractor		Commercial		Government-and-contractor	
	Short tons	Value	Short tons	Value	Short tons	Value	Short tons	Value
Alabama	1,169,000	$1,403,000	-----	-----	1,193,000	$1,411,000	83,000	$31,000
Alaska	180,000	556,000	200,000	$656,000	180,000	412,000	911,000	2,671,000
Arizona	2,484,000	3,149,000	16,000	16,000	4,117,000	4,881,000	6,625,000	7,292,000
Arkansas	1,745,000	2,728,000	-----	-----	3,186,000	3,833,000	1,709,000	2,616,000
California	26,371,000	31,395,000	491,000	599,000	26,927,000	31,258,000	8,705,000	7,818,000
Colorado	2,338,000	3,044,000	10,000	10,000	3,505,000	4,112,000	9,821,000	9,553,000
Connecticut	1,566,000	2,674,000	-----	-----	977,000	968,000	2,575,000	1,008,000
Delaware	133,000	294,000	-----	-----	485,000	395,000	-----	-----
Florida	W	W	-----	-----	W	W	12,000	24,000
Georgia	W	W	-----	-----	W	W	-----	-----
Hawaii	3,000	7,000	-----	-----	27,000	48,000	-----	-----
Idaho	364,000	497,000	489,000	279,000	2,062,000	1,918,000	4,072,000	3,972,000
Illinois	5,437,000	5,457,000	-----	-----	10,099,000	10,512,000	1,064,000	683,000
Indiana	3,625,000	4,153,000	-----	-----	6,274,000	6,494,000	642,000	363,000
Iowa	1,204,000	1,844,000	18,000	10,000	5,194,000	5,234,000	1,593,000	894,000
Kansas	438,000	401,000	70,000	44,000	1,432,000	1,168,000	1,333,000	607,000
Kentucky	614,000	697,000	-----	-----	863,000	1,043,000	376,000	257,000
Louisiana	4,600,000	5,807,000	188,000	75,000	3,598,000	4,625,000	170,000	210,000
Maine	284,000	306,000	-----	-----	663,000	506,000	10,157,000	3,994,000
Maryland	2,125,000	4,048,000	-----	-----	2,677,000	3,056,000	346,000	99,000
Massachusetts	2,960,000	3,976,000	-----	-----	2,679,000	2,565,000	1,553,000	755,000
Michigan	5,739,000	7,339,000	196,000	76,000	16,254,000	13,380,000	7,641,000	4,764,000
Minnesota	2,682,000	3,763,000	-----	-----	12,161,000	8,285,000	9,902,000	6,154,000
Mississippi	1,787,000	2,007,000	-----	-----	3,187,000	3,519,000	175,000	389,000
Missouri	2,595,000	3,033,000	-----	-----	1,279,000	1,139,000	679,000	569,000
Montana	501,000	676,000	961,000	1,213,000	1,419,000	1,312,000	10,970,000	12,562,000
Nebraska	1,153,000	1,400,000	-----	-----	4,837,000	5,651,000	2,567,000	2,510,000
Nevada	754,000	1,170,000	70,000	70,000	2,409,000	2,827,000	8,991,000	7,148,000
New Hampshire	573,000	813,000	-----	-----	801,000	989,000	3,386,000	1,193,000
New Jersey	2,839,000	4,829,000	-----	-----	1,517,000	1,731,000	-----	-----
New Mexico	973,000	1,298,000	285,000	306,000	2,256,000	3,069,000	3,604,000	3,660,000
New York	4,237,000	5,982,000	3,000	2,000	3,649,000	4,111,000	5,312,000	5,637,000
North Carolina	1,038,000	1,661,000	-----	-----	2,090,000	2,341,000	828,000	794,000
North Dakota	490,000	735,000	1,000	1,000	972,000	1,237,000	4,605,000	4,358,000

Ohio	5,745,000	7,009,000	-----	-----	12,208,000	14,688,000	250,000	92,000
Oklahoma	164,000	165,000	-----	-----	650,000	618,000	502,000	394,000
Oregon	2,081,000	2,559,000	192,000	285,000	4,465,000	5,517,000	8,364,000	12,730,000
Pennsylvania	3,137,000	4,550,000	-----	-----	2,978,000	4,507,000	-----	-----
Rhode Island	412,000	556,000	-----	-----	194,000	202,000	-----	-----
South Carolina	W	W	-----	-----	W	W	-----	-----
South Dakota	276,000	354,000	46,000	46,000	1,468,000	1,326,000	8,730,000	8,686,000
Tennessee	1,038,000	1,286,000	-----	-----	2,071,000	1,780,000	739,000	598,000
Texas	8,258,000	11,080,000	-----	-----	4,055,000	5,146,000	3,297,000	2,245,000
Utah	1,574,000	1,859,000	67,000	57,000	1,637,000	1,740,000	3,792,000	3,724,000
Vermont	163,000	238,000	-----	-----	487,000	664,000	446,000	148,000
Virginia	1,667,000	2,718,000	-----	-----	3,183,000	4,440,000	121,000	207,000
Washington	3,326,000	3,760,000	89,000	134,000	4,607,000	5,022,000	15,960,000	9,863,000
West Virginia	1,340,000	1,642,000	-----	-----	748,000	1,242,000	-----	-----
Wisconsin	3,270,000	2,769,000	112,000	62,000	10,579,000	7,663,000	7,889,000	4,633,000
Wyoming	207,000	286,000	11,000	5,000	1,473,000	1,661,000	3,375,000	3,392,000
Undistributed	1,100,000	1,784,000	-----	-----	1,385,000	2,153,000	-----	-----
Total	116,759,000	149,757,000	3,515,000	3,946,000	181,157,000	192,399,000	163,872,000	139,297,000
American Samoa	-----	-----	-----	-----	-----	-----	-----	-----
Panama Canal Zone	-----	-----	-----	-----	-----	-----	-----	-----
Puerto Rico	1,379,000	2,578,000	-----	-----	957,000	1,789,000	18,000	22,000

W Withheld to avoid disclosing individual company confidential data; included with "Undistributed."

TABLE 4.—Sand and gravel sold or used by producers in the United States in 1964, by States, uses and classes of operations—Continued

(Commercial unless otherwise indicated)

State	Gravel, construction—Continued										Gravel, miscellaneous	
	Railroad ballast		Fill				Other					
			Commercial		Government-and-contractor		Commercial		Government-and-contractor			
	Short tons	Value	Short tons	Value	Short tons	Value	Short tons	Value	Short tons	Value	Short tons	Value
Alabama	------	------	W	W	------	------	------	------	------	------	W	W
Alaska	350,000	$406,000	3,330,000	$1,835,000	20,419,000	$10,497,000	------	------	------	------	W	W
Arizona	W	W	693,000	370,000	------	------	------	------	------	------	18,000	$28,000
Arkansas	------	------	16,000	14,000	6,000	4,000	7,000	$17,000	------	------	15,000	6,000
California	170,000	193,000	2,727,000	2,449,000	1,054,000	881,000	557,000	553,000	124,000	$113,000	572,000	765,000
Colorado	W	W	341,000	405,000	400,000	349,000	------	------	------	------	119,000	146,000
Connecticut	------	------	742,000	388,000	W	W	77,000	83,000	W	W	203,000	220,000
Delaware	------	------	W	W	------	------	------	------	------	------	W	W
Florida	------	------	------	------	------	------	------	------	------	------	------	------
Georgia	------	------	------	------	------	------	------	------	------	------	3,000	7,000
Hawaii	------	------	------	------	------	------	------	------	------	------	------	------
Idaho	W	W	47,000	51,000	1,684,000	996,000	W	W	1,000	1,000	W	W
Illinois	175,000	158,000	735,000	486,000	20,000	11,000	W	W	------	------	120,000	101,000
Indiana	93,000	77,000	1,574,000	838,000	69,000	38,000	159,000	131,000	------	------	W	W
Iowa	W	W	235,000	163,000	------	------	W	W	25,000	6,000	23,000	14,000
Kansas	------	------	66,000	53,000	------	------	89,000	94,000	------	------	97,000	98,000
Kentucky	------	------	104,000	61,000	------	------	------	------	------	------	W	W
Louisiana	10,000	9,000	W	W	------	------	W	W	------	------	W	W
Maine	W	W	220,000	110,000	------	------	W	W	5,000	2,000	194,000	72,000
Maryland	W	W	1,662,000	883,000	------	------	655,000	812,000	86,000	20,000	W	W
Massachusetts	9,000	2,000	1,328,000	633,000	4,961,000	1,218,000	738,000	822,000	4,000	6,000	370,000	311,000
Michigan	210,000	225,000	350,000	203,000	347,000	141,000	276,000	341,000	52,000	16,000	142,000	116,000
Minnesota	431,000	251,000	942,000	513,000	258,000	88,000	28,000	15,000	13,000	5,000	157,000	125,000
Mississippi	33,000	17,000	W	W	------	------	W	W	8,000	8,000	W	W
Missouri	W	W	199,000	86,000	------	------	------	------	------	------	119,000	133,000
Montana	39,000	35,000	243,000	172,000	W	W	W	W	W	W	W	W
Nebraska	W	W	36,000	32,000	------	------	W	W	------	------	------	------
Nevada	5,000	11,000	297,000	314,000	10,000	10,000	W	W	22,000	23,000	------	------
New Hampshire	------	------	151,000	73,000	------	------	W	W	------	------	W	W
New Jersey	------	------	498,000	312,000	------	------	W	W	------	------	W	W
New Mexico	6,000	4,000	130,000	68,000	90,000	76,000	------	------	------	------	14,000	21,000
New York	W	W	1,811,000	1,027,000	3,801,000	2,417,000	W	W	------	------	504,000	432,000
North Carolina	63,000	54,000	5,000	6,000	46,000	37,000	------	------	------	------	603,000	1,143,000

North Dakota	468,000	288,000	244,000	194,000	------------	------------	------------	------------	------------	------------	14,000	7,000
Ohio	21,000	16,000	1,809,000	1,023,000	------------	------------	1,153,000	1,834,000	------------	------------	377,000	579,000
Oklahoma	W	W	W	W	884,000	328,000	------------	------------	------------	------------	W	W
Oregon	117,000	94,000	394,000	264,000	77,000	45,000	135,000	152,000	------------	------------	W	W
Pennsylvania	W	W	207,000	138,000	------------	------------	119,000	178,000	4,000	24,000	W	W
Rhode Island	------------	------------	263,000	96,000	------------	------------	W	W	------------	------------	W	W
South Carolina	W	W	------------	------------	------------	------------	------------	------------	------------	------------	W	W
South Dakota	24,000	21,000	54,000	34,000	------------	------------	------------	------------	------------	------------	------------	------------
Tennessee	W	W	W	W	------------	------------	W	W	------------	------------	W	W
Texas	43,000	39,000	157,000	85,000	186,000	74,000	159,000	153,000	------------	------------	112,000	242,000
Utah	23,000	7,000	378,000	146,000	176,000	92,000	W	W	------------	------------	377,000	471,000
Vermont	------------	------------	102,000	40,000	4,000	2,000	W	W	4,000	1,000	W	W
Virginia	------------	------------	W	W	------------	------------	39,000	66,000	------------	------------	W	W
Washington	306,000	187,000	1,884,000	1,248,000	386,000	224,000	290,000	256,000	356,000	307,000	150,000	205,000
West Virginia	W	W	W	W	------------	------------	13,000	8,000	------------	------------	------------	------------
Wisconsin	215,000	138,000	927,000	406,000	280,000	73,000	W	W	48,000	9,000	82,000	64,000
Wyoming	W	W	W	W	38,000	34,000	------------	------------	------------	------------	------------	------------
Undistributed	733,000	606,000	496,000	353,000	674,000	395,000	928,000	1,332,000	20,000	10,000	1,445,000	1,420,000
Total	3,544,000	2,838,000	25,397,000	15,572,000	35,870,000	18,030,000	5,422,000	6,847,000	772,000	551,000	5,830,000	6,726,000
American Samoa	------------	------------	------------	------------	------------	------------	------------	------------	------------	------------	------------	------------
Panama Canal Zone	------------	------------	------------	------------	------------	------------	------------	------------	------------	------------	------------	------------
Puerto Rico	------------	------------	589,000	482,000	124,000	108,000	------------	------------	------------	------------	------------	------------

W Withheld to avoid disclosing individual company confidential data; included with "Undistributed."

TABLE 5.—Sand and gravel sold or used by Government-and-contractor producers in the United States, by uses

(Thousand short tons and thousand dollars)

Year	Sand							
	Building		Paving		Fill		Other	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
1960	962	$1,374	26,042	$18,500	3,785	$2,122	728	$338
1961	2,321	3,331	32,243	21,621	7,991	3,256	435	242
1962	1,759	3,287	30,163	21,444	7,482	3,016	1,267	605
1963	728	882	33,285	23,840	7,076	3,124	1,433	668
1964	950	1,401	34,262	26,999	6,335	2,935	1,811	882

Year	Gravel								Total Government and contractor sand and gravel	
	Building		Paving		Fill		Other			
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
1960	7,320	$6,417	130,323	$93,859	17,106	$7,890	631	$522	186,897	$131,022
1961	6,480	9,372	148,572	109,155	13,510	4,547	677	493	212,229	152,017
1962	8,626	11,870	145,602	113,094	14,125	5,535	698	454	209,722	159,305
1963	4,110	4,091	157,671	132,829	26,379	21,476	497	366	231,179	187,276
1964	3,515	3,946	163,872	139,297	35,870	18,030	772	551	247,387	194,041

TABLE 6.—Sand and gravel sold or used by Government-and-contractor producers in the United States,[1] by types of producer

(Thousand short tons and thousand dollars)

Type of producer	1955-59 (average)		1960		1961	
	Quantity	Value	Quantity	Value	Quantity	Value
Construction and maintenance crews	48,658	$24,026	52,035	$31,212	54,030	$33,194
Contractors	127,912	86,595	134,862	99,810	158,199	118,823
Total	176,570	110,621	186,897	131,022	212,229	152,017
States	105,935	65,712	110,157	78,227	127,004	94,111
Counties	46,395	25,514	48,563	31,654	46,932	30,334
Municipalities	3,251	2,052	2,897	1,755	6,357	3,335
Federal agencies	20,989	17,343	25,280	19,386	31,936	24,237
Total	176,570	110,621	186,897	131,022	212,229	152,017
	1962		1963		1964	
	Quantity	Value	Quantity	Value	Quantity	Value
Construction and maintenance crews	55,547	$31,216	57,546	$35,945	64,820	$41,451
Contractors	154,175	128,089	173,633	151,331	182,567	152,590
Total	209,722	159,305	231,179	187,276	247,387	194,041
States	129,314	95,787	146,053	124,138	157,136	130,651
Counties	49,590	29,656	57,493	39,728	60,764	41,151
Municipalities	3,236	2,679	3,928	3,436	3,363	2,500
Federal agencies	27,582	31,183	23,705	19,974	26,124	19,739
Total	209,722	159,305	231,179	187,276	247,387	194,041

[1] Includes possessions and other areas administered by the United States (1955-56).

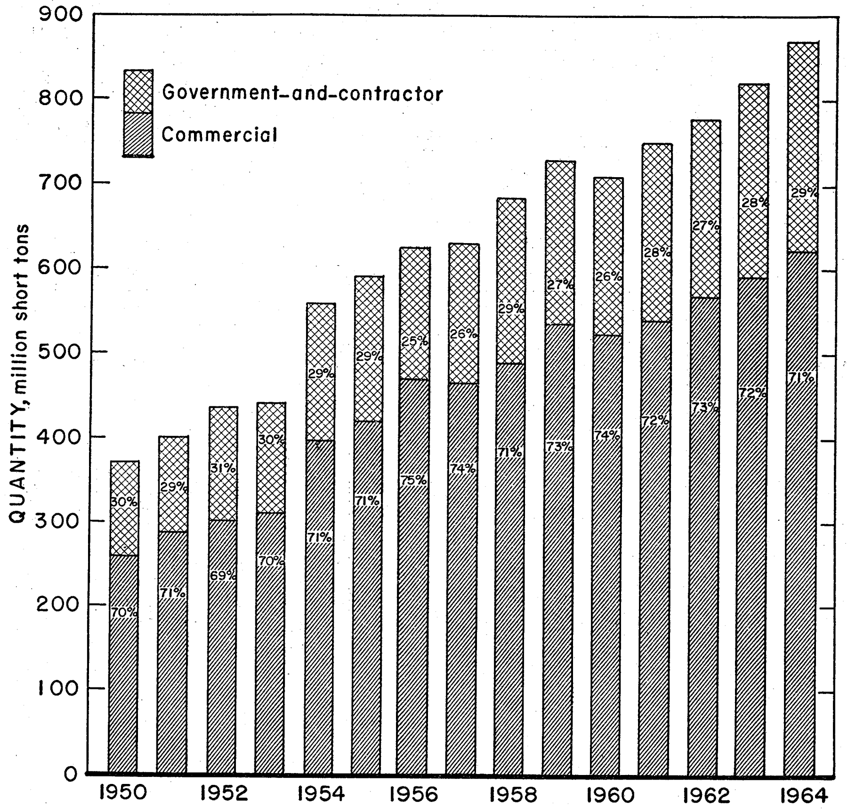

FIGURE 2.—Sand and gravel sold or used in the United States.

TABLE 7.—Sand and gravel sold or used by producers in the United States, by classes of operation and degrees of preparation

(Thousand short tons and thousand dollars)

	1963		1964	
	Quantity	Value	Quantity	Value
Commercial operations:				
Prepared	r 531, 829	r $626, 097	560, 391	$663, 737
Unprepared	58, 842	33, 899	61, 001	36, 314
Total	r 590, 671	r 659, 996	621, 392	700, 051
Government-and-contractor operations:				
Prepared	165, 519	142, 944	180, 974	158, 537
Unprepared	65, 660	44, 332	66, 413	35, 504
Total	231, 179	187, 276	247, 387	194, 041
Grand total	r 821, 850	r 847, 272	868, 779	894, 092

r Revised.

The trend toward precasting and prefabrication of building components continued without abatement. This development permits manufacture of concrete building components close to the sand and gravel source by efficient factory-type methods. The higher value product resulting from such operations generally can be economically shipped a greater distance than aggregate for use in poured-in-place concrete.

TABLE 8.—Number and production of domestic commercial sand and gravel plants by size of operation

Annual production (short tons)	1963				1964			
	Plants [1]		Production		Plants [1]		Production	
	Number	Percent of total	Thousand short tons	Percent of total	Number	Percent of total	Thousand short tons	Percent of total
Less than 25,000	2,528	43.3	51,217	8.7	2,259	39.7	38,210	6.2
25,000 to 50,000	895	15.3	32,702	5.5	892	15.7	31,807	5.1
50,000 to 100,000	[r] 897	15.4	[r] 64,447	10.9	952	16.8	66,415	10.7
100,000 to 200,000	756	13.0	103,874	17.6	744	13.1	104,617	16.8
200,000 to 300,000	301	5.1	73,542	12.4	326	5.7	78,893	12.7
300,000 to 400,000	[r] 149	2.6	[r] 50,847	8.6	167	2.9	56,508	9.1
400,000 to 500,000	85	1.5	36,998	6.3	112	2.0	49,708	8.0
500,000 to 600,000	44	.7	24,054	4.1	63	1.1	34,024	5.5
600,000 to 700,000	65	1.1	24,526	4.1	41	.7	26,469	4.3
700,000 to 800,000	23	.4	17,263	3.0	30	.5	22,501	3.6
800,000 to 900,000	22	.4	18,690	3.1	20	.4	15,018	2.4
900,000 to 1,000,000	16	.3	15,275	2.6	18	.3	16,898	2.7
1,000,000 and over	54	.9	77,236	13.1	61	1.1	80,324	12.9
Total	5,835	100.0	[r] 590,671	100.0	5,685	100.0	621,392	100.0

[r] Revised.
[1] Includes a few companies operating more than 1 plant but not submitting separate returns for individual plants.

TABLE 9.—Sand and gravel sold or used in the United States, by classes of operation and methods of transportation

	1963		1964	
	Thousand short tons	Percent of total	Thousand short tons	Percent of total
Commercial:				
Truck	[r] 502,231	61	531,490	61
Rail	59,271	7	59,338	7
Waterway	27,948	4	28,198	3
Unspecified	1,221	(1)	2,366	(1)
Total commercial	[r] 590,671	72	621,392	71
Government-and-contractor: Truck: [2]	231,179	28	247,387	29
Grand total	[r] 821,850	100	868,779	100

[r] Revised.
[1] Less than 0.5 percent.
[2] Entire output of Government-and-contractor operations assumed to be moved by truck.

Employment and Productivity.—In 1964, productivity was 8.5 tons per man hour compared with that of 7.5 tons in 1963.

CONSUMPTION AND USES

Commercial production of building sand and gravel totaled 264 million tons valued at $303 million, compared with that of 259 million tons valued at $295 million in 1963. Use of sand and gravel for paving increased both in tonnage and value. Production of sand and gravel for railroad ballast was practically unchanged.

Increases were noted in 1964 in unground sand for all uses except grinding, polishing, and filtration, in ground sand for all categories except abrasives. The expanding market for "specialty" silicas such as aerogels, hydrogels, hydrated silica, and pyrogenic silica products were discussed in a periodical.[3]

TABLE 10.—Ground sand sold or used by producers in the United States,[1] by uses

Use	1963		1964	
	Short tons	Value	Short tons	Value
Abrasives	281,409	$2,056,810	218,000	$2,184,000
Chemicals	15,723	173,063	18,000	164,000
Enamel	14,662	165,791	18,000	205,000
Filler	86,650	678,140	181,000	959,000
Foundry uses	145,410	1,076,401	172,000	1,414,000
Glass	105,481	714,649	152,000	775,000
Pottery, porcelain, and tile	202,535	2,107,898	230,000	2,467,000
Unspecified	186,996	1,945,367	197,000	1,994,000
Total	1,038,866	8,918,119	1,186,000	10,162,000

[1] Arkansas, California, Colorado (1964 only), Georgia, Idaho (1963 only), Illinois, Indiana, Louisiana (1964 only), Michigan, Minnesota, Mississippi (1963 only), Missouri, New Jersey, New York (1963 only), Ohio, Oklahoma, Pennsylvania, South Carolina, Texas, Virginia, Washington (1964 only), West Virginia, and Wisconsin.

PRICES

The average value reported for commercially produced sand and value was $1.13 per ton compared with that of $1.12 in 1963. Government and contractor producers reported an average value of $0.78 per ton compared with that of $0.81 in 1963. Representative prices per ton for construction sand and gravel in various metropolitan centers are published in Engineering News-Record. At yearend, the following price levels were reported for typical cities:

	Chicago	*Denver*	*New York*	*Los Angeles*
Gravel, 1½ inch	$3.78	$1.95	--------	$2.56
Gravel, ¾ inch	3.78	2.15	$3.20	2.76
Sand	4.13	1.47	2.65	2.41

These sample cities clearly indicate the great diversity of prices from market to market depending on local demand, availability of supply, and abundance or suitability of competing aggregates.

FOREIGN TRADE

The principal foreign trade in sand and gravel continued to be with Canada. Exports to Canada were 1,378,046 tons valued at $3,359,548, and imports from Canada were 443,191 tons valued at $557,722. Imports of glass sand were dominated by 40,207 tons valued at $124,886 from South Viet-Nam.

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[3] Oil, Paint and Drug Reporter. Silicas Market Keeps on Swelling: It All Depends on the Various Types. V. 185, No. 14, Apr. 6, 1964, p. 41.

TABLE 11.—U.S. imports for consumption of sand and gravel by classes

Year	Sand				Gravel		Total	
	Glass sand [1]		Sand, n.s.p.f., crude or manufactured					
	Short tons	Value	Short tons	Value	Short tons	Value	Short tons	Value
1955–59 (average)	1,590	[2] $300,349	321,290	$445,074	25,446	$24,509	348,326	$769,932
1960	10,765	37,111	379,673	515,837	3,752	5,423	394,190	558,371
1961	2	[2] 1,602	335,005	440,759	43,287	44,009	378,294	486,370
1962	31,416	63,950	307,637	414,703	29,198	31,948	368,251	510,601
1963	22,724	68,650	336,547	430,165	(3)	(3)	359,271	498,815
1964	40,308	127,639	443,213	558,178	(3)	(3)	483,521	685,817

[1] Classification reads: "Sand containing 95 percent or more silica and not more than 0.6 percent oxide of iron, and suitable for manufacturing glass."

[2] Consists mainly of synthetically prepared silica from West Germany for specialized uses and is not comparable in value to ordinary glass sand.

[3] Sand, n.s.p.f. crude or manufactured and gravel no longer separately classified.

Source: Bureau of the Census.

WORLD REVIEW

United Kingdom.—Systematic planning for restoration of farming land prior to extraction of gravel was used during 1964 to achieve excellent results.[4] An excellent summary was published on the origin, properties, and use of British sand and gravel.[5] Specifications and use of gravel in bituminous road surfaces were discussed.[6]

TECHNOLOGY

General.—An increasing number of local and State governments are demanding reclamation of worked-out sand and gravel pits. To assist producers in meeting the problems of land rehabilitation and restrictive zoning regulations, the National Sand and Gravel Association prepared two books.[7]

Closed television monitoring, installed in the control tower, enabled the materials control engineer of a Denver, Colo., sand and gravel plant to follow all phases of production.[8]

The general aspects of the chemical and physical impurities in sands used for concrete aggregates were discussed. Shortcomings of present methods for testing were noted, and it was concluded that much further research was needed to distinguish the harmful impurities from the harmless.[9]

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[4] Goodland, N. L. The Restoration to Farming Land of Worked-Out Gravel Pits. Cement, Lime and Gravel (London), v. 40, No. 1, January 1965, pp. 13–17.

[5] Tomkeieff, S. I. The Economic Geology of Quarried Materials—Sand and Gravel. Quarry Managers J. (London), v. 48, No. 7, July 1964, pp. 255–262.

[6] Alcock, J. D. Coated Gravel. Quarry Managers J. (London), v. 48, No. 3, March 1964, pp 98–102.

[7] Ahearn, Vincent P. Jr. Land Use Planning and the Sand and Gravel Producer. National Sand and Gravel Association, Silver Spring, Md., 1964, 30 pp.

Schellie, Kenneth L., and David A. Rogier. Site Utilization and Rehabilitation Practices for Sand and Gravel Operations. National Sand and Gravel Association, Silver Spring, Md., 1963, 80 pp.

[8] Rock Product Mining and Processing. Automated Gravel Plant Adds TV. V. 67, No. 2, February 1964, pp. 96–98.

Dredging.—Diesel-powered, slewing crane dredges were developed to work shallow but extensive sand and gravel deposits.[10]

Sand and gravel to meet the differing specifications of Ohio, Pennsylvania, and West Virginia, were produced from the Ohio River by a floating processing plant mounted on a surplus government dredge.[11]

A highly automated floating sand and gravel plant produced 600 tons per hour from the James River, near Richmond, Va. Crushing, screening, and washing operations were all controlled by a pushbutton console.[12]

Processing Equipment.—The various types of equipment in present-day use for the wet recovery and classification of sands were described and illustrated.[13]

All processing and handling operations at a Perrysville, Ohio, plant were regulated from a centralized control room, with interlocked equipment and emergency pushbutton stations. Pit deposits, for production of uncrushed aggregate, were subjected to heavy media separation using a slurry of magnetite and ferrosilicon in a 50–50 ratio.[14]

A comprehensive summary of research conducted on a series of proprietory flocculating agents was published.

Twelve flocculating agents were tested, and the water solubilities, comparable costs, and relative efficiencies on various effluents were tabulated.[15]

Foundry Sand.—A catalyzed dextrose binder was used for core mixes and for dry sand molding mixes in casting heavy parts of manganese steel, carbon, and alloy steels, for railroad, earthmoving and heavy construction equipment. The binder was found to be exceptionally valuable for olivine sand cores.[16]

Machinery was developed for the automatic forming of green sand molds without the use of flasks. Standard green sand mixes were used and the molds produced were free from fins, had high precision, and patterns could be changed quickly. Production rate was one mold each 15 seconds.[17]

A Russian core mixture, for steel castings, was composed of 65 to 70 percent dry sand, 30 to 35 percent used sand, 3 to 3.5 percent of sulfite alcohol from fermentation of sulfite waste liquor, 0.1 to 0.2 percent of industrial urea, and 1 percent water. Cores were coated with zircon to improve surface.[18]

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[9] Jordan, J. P. R. The Problems of Impurities in Sands. Cement, Lime and Gravel (London), v. 39, No. 11, November 1964, pp. 367–368.

[10] Cement, Lime and Gravel (London). The Use of Slewing Crane Dredgers for Sand and Gravel Extraction in the Rhine Valley. V. 39, No. 9, September 1964, pp. 295–300.

[11] Levine, Sidney. Delta Concrete Wins the Battle of the Muddy River Bottom Rock Products, v. 67, No. 11, November 1964, pp. 61–63.

[12] Trauffer, Walter E. Southern Materials. Pit and Quarry, v. 57, No. 3, September 1964, pp. 86–93, 102.

[13] Sidebottom, J. B., and F. W. Raspass. The Upgrading of Fines by Wet Processes. Quarry Managers J., v. 48, No. 6, June 1964, pp. 227–242.

[14] Rock Products. For Flexibility, Functionalize. V. 67, No. 2, December 1964, pp. 86, 88.

[15] Jordan, J. P. R., and A. R. Roeder. Some Experiments With Flocculating Agents. Cement, Lime, and Gravel (London), v. 39, No. 5, May 1964, pp. 165–172.

[16] Hohn, Francis H. Using Catalyzed Dextrose Binder in Dry Sand Molds. Foundry, v. 92, No. 10, October 1964, pp. 186–192.

[17] Iron Age. Sand Castings Gain Precision With Flaskless Molds. V. 193, No. 19, May 7, 1964, pp. 78–79.

[18] Foundry. Core Mixture. V. 92, No. 1, January 1964, p. 108.

The problems associated with foundry use of wet frozen, or frosted molding sands, and suggested solutions for overcoming these problems were discussed.[19]

Glass.—Higher efficiency in melting glass was made possible by utilizing the electrical conductivity of the glass itself to develop melting conditions. Molybdenum electrodes were used to carry electricity into the mass of molten glass.[20]

A process was developed for toughening, and making more abrasion-resistant, glass containers. The composition and physical properties of the glass were changed by spraying a form of titanium oxide upon the glass when the red hot glass was being blown.[21]

The Ford Motor Co. planned a multimillion dollar conversion of its Nashville, Tenn., glass plant to manufacture flat glass by the float process. Conversion is planned to be complete in 1966.[22]

Special Silicas.—Complex shapes of high dimensional accuracy were formed by slip casting particulate, fused amorphous silica.[23]

Development of a fumed colloidal silica, having an exceptionally high surface area, for use as a thickener in polyester resins was reported.[24]

Experimental data were used to evaluate the effect of additions of sodium silicate on the filtration rate of asbestos fibers. A definite increase in rates of filtration was obtained.[25]

Coprecipitation of a hydrous silica and hydrous zirconia from an aqueous solution, followed by drying and calcining of the coprecipitated mixture, produced a hydrocracking catalyst.[26]

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[19] Sanders, Clyde A. Winter Weather Can Cause Scrap Castings. Foundry, v. 92, No. 2, February 1964. pp. 48–50.

[20] Olson, Carl R. The Jeannette Glass Story: The Electrical System. Ceramic Age, v. 80, No. 3, March 1964, pp. 28–30.

[21] Chemical Trade Journal and Chemical Engineer (London). UK Company's Break-through With Titanium-Toughend Glass Know-how. V. 154, No. 4002, Feb. 21, 1964, p. 251.

[22] Wall Street Journal. Ford Motor to Convert Glass Plant at Nashville to the "Float" Process. V. 164, No. 93, Nov. 9, 1964, p. 3.

[23] NASA Tech Brief. Refractory Ceramic has Wide Usage, Low Fabrication Cost. National Aeronautics and Space Administration Brief 63–10481, April 1964, 2 pp.

[24] Chemical Week. Countdown, New Chemicals. V. 95, No. 21, Nov. 21, 1964, p. 53.

[25] Martinez, Edward. The Effect of Sodium Silicate on the Filtration Rate of Asbestos Fiber. Canadian Min. and Met. Bull. (Montreal), v. 57, No. 630, October 1964, pp. 1042-1044.

[26] Hansford, Rowland C., and Dean Arthur Young (assigned to Union Oil Co. of California, Los Angeles) Composite Silica-Zirconia Hydrocracking Catalyst and Process. U.S. Pat. 3,120,483, Feb. 4, 1964.

Silicon

By John L. Morning[1]

◆

SHIPMENT of high purity silicon recovered from an offyear in 1963 which saw the growth of this industry slowed down as a result of changes in technology. Production of polycrystal silicon remained at about the same level, but shipments increased 34 percent over those of 1963. Reflecting industry stability, the price of polycrystal silicon remained at the same level it had held since April 1963. Three producers announced plant expansion plans.

Metallurgical grade silicon metal production increased 8 percent while shipments increased 10 percent over those of 1963.

TABLE 1.—Production, shipments, and value of high-purity silicon in the United States

Type	1963			1964		
	Production (kilograms)	Shipments		Production (kilograms)	Shipments	
		Quantity (kilograms)	Value (thousands)		Quantity (kilograms)	Value (thousands)
Polycrystal	34,582	24,539	$3,041	35,020	32,781	$3,448
Single crystal rods[1]	4,243	3,574	3,642	8,821	7,150	8,586

[1] Does not include data for companies producing single-crystal high-purity silicon solely from scrap and other secondary and purchased polycrystal.

DOMESTIC PRODUCTION

Primary producers and plant location of polycrystal silicon were as follows:

Allegheny Electronics Chemical Co., subsidiary of Metals Hydride, Inc	Lewis Run, Pa.
Dow Corning Corp	Hemlock, Mich.
General Diode Corp	Framingham, Mass.
Monsanto Co	St. Charles, Mo.
Texas Instruments, Inc	Dallas, Tex.

High-purity silicon producers announcing plant expansions in 1964 were Monsanto Co. with a tenfold increase in epitaxial facilities, Allegheny Electronics Chemical Co. with a fivefold increase in epitaxial production equipment, and Dow Corning Corp. expanding its Hemlock, Mich., plant to twice its present capacity by early 1965.

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[1] Commodity specialist, Division of Minerals.

Union Carbide Corp. announced its entry into device manufacturing with a new plant at Palo Alto, Calif.

Metal Hydrides, Inc., of Beverly, Mass., purchased all of the stock of Allegheny Electronics Chemical Co. which will be operated as a wholly owned subsidiary. Metal Hydrides has facilities for crystal production, zone refining, polishing, lapping, and slicing.

TABLE 2.—Production, shipments, and stocks of silvery pig iron, ferrosilicon, and silicon metal in 1964

(Short tons)

Alloy		Producers stocks as of Dec. 31, 1963	Production	Shipments	Producers stocks as of Dec. 31, 1964
Type	Silicon content (percent)				
Silvery pig iron	5-13	[r] 25,890	70,922	73,806	23,006
Do	14-20	18,727	149,992	150,451	18,268
Ferrosilicon	21-55	41,965	351,998	358,479	35,484
Do	56-70	5,142	41,188	43,037	3,293
Do	71-80	13,777	63,662	71,244	6,195
Do	81-89	2,903	14,980	16,351	1,532
Do	90-95	590	1,391	1,628	353
Silicon metal	96-99	5,998	69,423	71,590	3,831
Ferrosilicon briquets	40-50	4,086	63,068	63,854	3,300
Miscellaneous silicon alloys	------------	3,564	13,500	15,009	2,055

[r] Revised.

Silicon metal was produced in nine plants of eight companies as follows:

Company:	*Plant location*
Interlake Steel Corp. (formerly Interlake Iron Corp.)	Beverly, Ohio
Keokuk Electro-Metals Co., division of Vanadium Corporation of America	Wenatchee, Wash.
National Metallurgical Corp., subsidiary of Apex Smelting Co	Springfield, Oreg.
Ohio Ferro-Alloys Corp	Powhatan Point, Ohio
Do	Tacoma, Wash.
Pittsburgh Metallurgical Co	Charleston, S.C.
Reynolds Metals Co	Sheffield, Ala.
Tennessee Products & Chemical Corp	Rockwood, Tenn.
Union Carbide Corp., Mining & Metals Division	Alloy, W. Va.

The National Metallurgical Corp., silicon metal producer, completed an expansion to increase production by 40 percent.

Interlake Steel Corp. (formerly Interlake Iron Corp.) placed in operation a $4 million 29,000 kilovolt-amperes submerged arc electric furnace which will be used to produce silicon alloys and silicon metal at Beverly, Ohio. The highly automated furnace has interchangeable hearths, which allows quick changeover of hearths to produce different types of silicon products. The largest hearth is 34 feet in diameter.

Dow Corning Corp. placed two new silicone plants in production early in the year. The medical products plant at Hemlock, Mich., is said to be the first plant built for this type of product. A plant located at Elizabethtown, Ky., will manufacture silicone sealants for virtually all major industries. Plans were announced to build a silicone rubber compounding plant at Trumbull, Conn., to be completed early in 1965.

Union Carbide Corp. announced an expansion of their Sistersville, W. Va., silicone plant to strengthen their position in this growing industry.

TABLE 3.—Consumption by major end uses, and stocks, of silicon alloys in the United States in 1964

(Short tons)

Alloy		Stainless steels	Other alloy steels[1]	Carbon steels	Tool steels	Steel mill rolls	Gray and malleable castings	Aluminum base alloys	High temperature alloys	Other nonferrous alloys	Miscellaneous uses	Total consumption	Consumers stocks Dec. 31, 1964
Type	Silicon content (percent)												
Silvery pig iron	5–13		511	813		1,046	95,333				1,881	99,584	8,722
Do	14–20		6,658	22,622		121	83,660			52	[3] 3,694	116,807	16,812
Ferrosilicon	[2] 21–55	7,930	69,223	93,008	988	1,225	91,223	77	243	2,838	[4] 19,512	286,267	27,196
Do	56–70	70	6,936	17,836			970				[4] 3,117	28,929	2,235
Do	71–80	9,998	15,055	6,915	317	239	11,045		17	29	13,523	57,138	6,731
Do	81–89	116	456	2,154		168	5,603			22	10	8,529	1,222
Do	90–95	17	1,310	159		57	323	3,030		58	14	4,968	730
Silicon metal	96–99	44	738	42	4		193	46,392	829	703	[5] 9,285	58,230	3,519
Ferrosilicon briquets	40–50		118	281		4	37,988					38,391	4,561
Miscellaneous silicon alloys [6]		310	6,226	5,127	59	136	18,631	129	65	53	4,127	34,863	4,507

[1] Includes quantities of carbon steels because some firms failed to specify individual uses.
[2] Mainly from 40 to 55 percent silicon.
[3] Used mainly in high-silicon iron, and to beneficiate ores.
[4] Used mainly in producing ferronickel.
[5] Used mainly in producing silicones and other chemical compounds.
[6] Includes calcium-silicon, calcium-manganese-silicon, silicon-manganese-zirconium, silicon carbide, Ferrocarbo (including briquets), Alsifer, and other miscellaneous silicon alloys.

CONSUMPTION AND USES

The consumption of high-purity silicon was mainly in fabricating rectifiers, diodes, transistors, and integrated circuitry electronic components. Continued research and development, together with improvements in manufacturing techniques for integrated circuits on small chips of silicon, brought increased demand for these units. Silicon integrated circuits have been developed for hearing aids and the new IBM 360 computer. Automated production has made silicon semiconductors competitive with germanium for home entertainment appliances. One automobile manufacturer was said to have purchased $1 million worth of silicon diodes for automotive applications.

Silicon controlled rectifiers gained wide acceptance in alternating current power engineering during 1964. These devices make possible a continuously variable speed or power control and feature faster time response and precision control. Applications include control systems for cranes, steel mill power drives, and household appliances.

Interest has developed in a silicon germanium semiconductor alloy, as a thermoelectric generator, for direct conversion of electricity from industrial and domestic waste heat. Demonstration units have been fabricated which operate at 750° C to 800° C and are able to handle peak temperatures up to 1,300° C. The demonstration units represent 100 kilowatts of power per cubic foot which would weigh about 16 pounds.

Silicon metal was used as the starting material in the production of silicone products such as chemicals, oils, resins, lubricants, and elastomers. These manmade versatile products were used in a wide range of industries. Specific interest in 1964 was in applications for molding compounds for incapsulating semiconductor devices, in foaming agents for making urethane foam, in compounds for spraying high-voltage insulators to protect against flashovers caused by airborne contamination, and in production of medical silicone products used in corrective plastic and dental surgery.

The increased consumption of 50 percent ferrosilicon reflected the rise in iron and steel production in 1964.

STOCKS

Producer and consumer stocks moved in opposite directions. Producer stocks dropped 20 percent or 24,000 tons while consumer stocks rose about the same quantity but at the much higher rate of 43 percent.

PRICES

High-purity polycrystal silicon with greater than 100-ohm-centimeter resistivity for semiconductor use is nominally priced at $123 per kilogram. No price change for this grade of material has been announced since early in 1963, indicating the stability this industry has achieved. Single crystal silicon prices were more competitive and being dependent on individual customers specifications, were subject to a wide range of prices. The average value for 1964 shipments of single crystal silicon rod was $1,200 per kilogram.

The price of 50-percent ferrosilicon carload lots, bulk, delivered at the beginning of the year was 12.1 cents per pound contained silicon. The price increased in July to 12.6 cents and in September, to 13.6 cents, the price at which it closed the year.

Metallurgical grade silicon, 98 percent minimum silicon, 0.35 maximum iron, opened the year at 17.5 cents per pound contained silicon, carload lots, bulk, delivered, and it closed the year at 19 cents, with price increases in July and September.

FOREIGN TRADE

High-purity silicon imports for consumption totaled 2,637 kilograms with a value of $344,972. Federal Republic of Germany supplied 96 percent of the imports with the remainder coming from France, Japan, and Belgium-Luxembourg. The average value of these imports was $131 per kilogram.

The value of ferrosilicon exports increased 30 percent over those of 1963. Canada and Mexico received 37 and 29 percent respectively, with the balance of the exports being received by 18 countries.

TABLE 4.—U.S. imports for consumption of ferrosilicon and silicon metal, by grades and countries

	1962			1963			1964		
	Short tons		Value	Short tons		Value	Short tons		Value
	Gross weight	Silicon content		Gross weight	Silicon content		Gross weight	Silicon content	
Ferrosilicon:									
8 percent and less than 60 percent silicon:									
Canada	15,172	2,359	$782,588	12,781	1,962	$667,616	10,978	1,672	$569,696
Germany, West	1,086	163	180,948	38	5	4,850	358	53	59,714
Japan	-------	-------	-------	-------	-------	-------	97	45	30,498
Outer Mongolia	-------	-------	-------	-------	-------	-------	9	1	538
Total	16,258	2,522	963,536	12,819	1,967	672,466	11,442	1,771	660,446
60 percent and less than 80 percent silicon:									
Canada	53	37	9,366	-------	-------	-------	504	343	84,307
France	11	8	1,873	132	101	17,326	40	31	5,629
India	-------	-------	-------	-------	-------	-------	1	1	284
Italy	-------	-------	-------	22	17	2,959	-------	-------	-------
Norway	5	4	845	291	220	38,739	1,125	857	145,898
South Africa, Republic of	2	2	272	-------	-------	-------	-------	-------	-------
Total	71	51	12,356	445	338	59,024	1,670	1,232	236,118
80 percent and less than 90 percent silicon:									
Italy	-------	-------	-------	-------	-------	-------	49	42	11,823
Grand total	16,329	2,573	975,892	13,264	2,305	731,490	13,161	3,045	908,387
Silicon: Canada	12	12	5,015	-------	-------	-------	-------	-------	-------

Source: Bureau of the Census.

TABLE 5.—U.S. exports of ferrosilicon

Year	Short tons	Value	Year	Short tons	Value
1955-59 (average)	3,838	$533,147	1962	4,101	$1,348,661
1960	5,501	867,140	1963	3,130	947,773
1961	34,764	6,104,913	1964	5,785	1,232,450

Source: Bureau of the Census.

WORLD REVIEW

EUROPE

Norway.—A new silicon carbide plant was completed by the Norton Company at Lillesand, South Norway, with an annual capacity of 8,000 tons. A subsidiary, Norton A/S, will operate the plant with the carbide being shipped to other Norton subsidiary companies in Europe for further processing.

The ferrosilicon industry in Norway reached a record output of 235,000 short tons in 1964. Shipments were made to the United Kingdom, West Germany, Belgium, and Luxembourg.

United Kingdom.—Monsanto Chemicals, Ltd. planned expansion to double output of high-purity silicon at its Buabon plant in North Wales, was near completion at the end of 1964. Purpose of the expansion is to meet rising home demand and to increase exports to Europe. Monsanto was the larger of the two high-purity silicon producers in the United Kingdom, the other being Uclaf Ltd.[2]

A proposed additional 15 percent surcharge on imports by the United Kingdom, including silicon metal, raised a storm of protest by the Association of Light Metal Alloy Refiners and Smelters representing the main users of silicon metal. At the end of the year, the Board of Trade announced the surcharge would not apply to imported silicon metal.[3]

ASIA

India.—It was reported that the infant transistor industry in India is facing serious competition from heavy Japanese imports. A research facility in Delhi, has been established to develop solid-state miniaturized electronic equipment for India's armed forces. Indian Metals and Ferro Alloys, Ltd., ordered for its plant at Theruvali, Orissa, a 10,000 kilovolt-amperes rotating ferrosilicon furnace from Norway. Startup of the plant was scheduled for 1966.

Japan.—The Japan Society of Newer Metals annual report shows six primary producers of semiconductor grade polycrystalline silicon with a monthly capacity of 1,470 kilograms per month. Since 1959, production of high-purity silicon has steadily increased with imports decreasing until Japan has become self-sufficient in this commodity. Estimated demand for 1964 of single crystal silicon was 4,110 kilograms for use in transistors (29 percent), diodes (9 percent), rectifiers (56 precent), and other items (6 percent).

AFRICA

South Africa, Republic of.—Standard Telephones and Cables (Pty.), Ltd. (S.T.C.), opened a plant at Boksburg (Transvaal) in September for producing planar silicon transistors. Plans call for producing integrated circuit devices as a second-stage expansion. Announcement of a silicon rectifier-power source to supply a direct-current output of 3.2 megawatts (24,000 amperes at 132 volts) for use by an electrolytic manganese plant was made by S.T.C. The equipment contains 672 high-power hermetically sealed silicon diodes with full protective equipment.[4]

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[2] Chemical Week. V. 94, No. 3, Jan. 18, 1964, p. 39.

[3] Metal Bulletin. (London). No. 4954, Dec. 8, 1964, p. 17.

TECHNOLOGY

The density of high-purity silicon has been determined to be 2.329002± (7×10^{-6}) grams per cubic centimeter at 25° C. This high precision measurement is in general agreement with other investigations. Density is used along with other factors in determining some physical constants.[5]

Research quantities of a new form of semiconductor grade silicon described as dendritic grown web crystal silicon was introduced by a primary producer. This material is made in widths of 3 to 8 millimeters, thicknesses of 50 to 250 millimeters, and lengths of 50 centimeters. Claims of manufactured micro smoothness superior to present polishing techniques and improved crystallographic properties are features of this new type of silicon. Elimination of numerous surface preparation steps and continuous processing may result from this development.[6]

Integrated circuitry, the miniaturization of complex electronic devices, continued to be developed and accepted for use in guidance and control systems of aerospace crafts. Commercial applications of micro radios, hearing aids and voltage regulators for automobiles are being developed. Most device makers introduced new semiconductor integrated circuitry devices in 1964.[7]

Silicon solar cells have been made in the past by adding boron or phosphorous to high-purity silicon. A new development in the continuing process of improving performance of these cells was announced by the National Aeronautical and Space Administration's Lewis Research Center. Aluminum substituted for boron or phosphorous has increased the power output and resistance to radiation damage of these devices.[8]

Silicon solar cells are receiving competition from other semiconductor materials such as polycrystalline cadmium sulfide, cadmium teluride, gallium arsenide, and zinc sulfide. However, single crystal silicon has higher conversion efficiencies than these other materials and to meet competition larger area silicon solar cells are being developed. Larger area cells eliminate some processing steps, reduce the number of leads and contacts, and lower the total weight of the system. Successful development of these larger area, lighter weight, and therefore less expensive cells could expand the use of these devices.[9]

A 30-day orbital test of solar cells will be conducted in mid-1965 by the Air Force. Test panels of conventional silicon, webbed silicon, gallium arsenide, and cadmium sulfide will be compared for performance in space.[10]

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[4] South African Mining and Engineering Journal. V. 75, pt. 2, No. 3727, July 10, 1964, p. 309.

———. V. 75, pt. 2, No. 3739, Oct. 2, 1964, p. 947.

[5] Henins, Ivar. Precision Density Measurement of Silicon. NBS J. Res., v. 68A (Physics and Chemistry), No. 5, September–October 1964, pp. 529–533.

[6] Currin, C. G., and E. Earleywine. Advances in Elemental Semiconductors. Semiconductor Products and Solid State Technology. V. 7, No. 6, June, 1964, pp. 20–25.

Electronic News. Si in New Form at Dow Corning. V. 9, No. 416, Feb. 10, 1964, p. 37.

[7] Getler, M., and R. Pay. AF outlines Future Solid-State R&D. Missiles and Rockets, Aug. 31, 1964, pp. 14–15.

[8] Chemical Week. V. 94, No. 24, June 13, 1964, p. 66.

[9] Chemical Week. V. 95, No. 21, Nov. 21, 1964, pp. 77–78.

Epitaxial technology continues to grow with a host of technical papers on methods of deposition of both silicon and silicon dioxide,[11] methods of adding dopants,[12] and studies of surface preparation.[13]

Single crystal silicon carbide can be made by vapor phase sublimation of silicon carbide, cracking compounds of silicon tetrachloride and carbon tetrachloride in the presence of hydrogen, and vaporization of elemental silicon and carbon. In a study [14] using the latter method, growth rates and quality of growth were investigated. Good quality single crystal epitaxial layers of silicon carbide were grown at 0.5 micron per minute.

Small quantities of silicon nitride (Si_3N_4) fibers were successfully grown, using inexpensive silicates in laboratory experiments at the Bureau's Norris Research Laboratory. Aluminum silicate (firebrick) was reduced with carbon, aluminum, or silicon metal at 1,400° C in a nitrogen atmosphere. The fibers produced had excellent thermal shock resistance and good oxidation resistance to about 1,260° C.[15]

Silicone technology continues to grow with a large number of new products being introduced. No disclosure of processes or methods of manufacture was made in this growing highly competitive industry.

A silicon free-machining core iron containing 2.5 percent silicon for use in solenoid switches, armatures, pole pieces, relays, and other devices requiring magnetic core components was introduced by the Carpenter Steel Company. Claims are made of 40 percent increase in machinability when using automatic screw machines.[16] Typical analysis of this material consists of carbon 0.05 percent maximum, manganese 0.40 percent maximum, silicon 2.25 to 2.75 percent, phosphorous 0.08 to 0.15 percent, and balance iron.

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[10] Electronic News. V. 9, No. 464, Dec. 7, 1964, p. 41.

[11] Mayer, S. E., and D. E. Shea. Epitaxial Deposition of Silicon Layers by Pyrolysis of Silane. J. Electrochem. Soc., v. 111, No. 5, May 1964, pp. 550–556.

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[12] Chapelle, T. J., and H. B. Heller. Phosphorous Nitride as a Diffusion Source for Silicon. Trans. AIME, v. 230 (Met. Soc.), March 1964, pp. 311–314.

Matukura, Y., K. Suzuki, and Y. Miura. Incorporation of Boron Into Epitaxially Grown Silicon. J. Electrochem. Soc., v. 111, No. 4, April 1964, pp. 491–492.

Schmidt, P. F., and A. E. Owen. Anodic Oxide Films for Device Fabrication in Silicon. J. Electrochem. Soc., v. 111, No. 6, June 1964, pp. 682–688.

[13] Chu, T. L., and R. L. Tallman. Water Vapor as an Etchant for Silicon. J. Electrochem. Soc., v. 111, No. 11, November 1964, pp. 1306–1307.

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[14] Brander, R. W. Epitaxial Growth of Silicon Carbide. J. Electrochem. Soc., v. 111, No. 7, July 1964, pp. 881–883.

[15] Johnson, Robert C., and Wilbur H. Warwick, and H. R. Shell. Synthesis and Some Properties of Fibrous Silicon Nitride. BuMines Rept. of Inv., 6467, 1964, 25 pp.

[16] American Metal Market. V. 71, No. 229, Nov. 27, 1964, p. 19.

Silver

By J. Patrick Ryan[1]

⁂

FEATURES of silver in 1964 were a strong demand for silver coins and a sharp rise in the quantity of silver used in coinage, extraordinary stability in the prompt-delivery price, a sharp reduction in Treasury silver stocks, and a significant increase in industrial consumption of silver. The worldwide imbalance between new production and consumption of silver created much concern about the future supply and prompted much buying for speculation and inventory. The resulting high level of trading on the Commodity Exchange brought new highs in prices for future delivery. Several bills to solve the coinage problem and alleviate the shortage in new supply were introduced, and hearings were held by congressional committees.

Mine output increased slightly, owing chiefly to increased production of silver-bearing copper ores. Exports of silver exceeded imports for the first time since World War II. The use of silver increased in all major industrial categories. About 36 percent of the silver used in coinage went into minting Kennedy half dollars, virtually all of which were withdrawn by collectors and speculators.

World production of silver decreased slightly, but consumption in the arts and industries and for coinage increased sharply over the 1963 figures.

LEGISLATION AND GOVERNMENT PROGRAMS

Several bills relating to silver were introduced in the 2d Session of the 88th Congress. Hearings were held on April 1 and 2, 1964, by the Senate Banking and Currency Committee and on August 13 by the House of Representatives Committee on Banking and Currency on bills dealing with the silver content of coins, Treasury stocks of silver, and the monetary value of silver. The following bills were considered at the hearings: To redefine the silver content in silver coins (H.R. 10534, S. 2671); to prohibit the sale of silver bullion by the Secretary of the Treasury (H.R. 10561, S. 2716); to increase the monetary value of silver to $2.5858 per ounce (H.R. 10560, S. 2717); and to provide for a study and report to Congress by the Secretary of the Treasury concerning the silver policy of the United States (H.J. Res. 1140, S.J. Res. 190). Further action on the proposed legislation was deferred.

The following bills also were introduced: To provide for the sale of silver dollars (S. 2715, S. 2743, S. 2749, H.R. 11551); to build a new mint (H.R. 11145, S. 2735); to let private industry mint coins (H.R.

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[1] Commodity specialist, Division of Minerals.

11217); to inscribe 1964 on all coins (H.R. 11912, S. 2950); and to revitalize the San Francisco mint (H.R. 12236, S. 3072). These bills were referred to the respective Committees on Banking and Currency of the House of Representatives and the Senate, but no further action was taken. A bill to prohibit profiteering in initial distribution of coins (H.R. 11918) was referred to the Committee on the Judiciary.

Seven contracts totaling $520,486 were executed during the year under the Government program of financial assistance administered by the Office of Minerals Exploration (OME). The Government share of the exploration cost was 50 percent. OME announced that Federal financial assistance for silver exploration would be increased to 75 percent for contracts executed on or after September 30, 1964. The following exploration contracts for silver or silver-gold were active or in force during the year:

Operator	Location	Total cost
Baker and Davis	Esmeralda County, Nev	$36,528
Lombardi, Clemens, A., and Arthur	Lemhi County, Idaho	86,670
Oregon King Consolidated Mines, Inc	Jefferson County, Oreg	55,150
B.L.M.W. Mining Co	Madison County, Mont	20,550
Resource Americas Corp. and Associates	San Bernardino County, Calif	32,088
Wayne Erickson	Beaverhead County, Mont	61,560
Cortez Joint Venture	Lander County, Nev	227,940
Total		520,486

TABLE 1.—Salient silver statistics

	1955–59 (average)	1960	1961	1962	1963	1964
United States:						
Mine production thousand troy ounces	35,878	30,766	34,794	36,798	35,243	36,334
Value thousands	$32,471	$27,846	$32,166	$39,929	$45,076	$46,980
Ore (dry and siliceous) produced:						
Gold ore thousand short tons	2,310	2,267	2,060	2,159	2,460	2,631
Gold-silver ore do	145	347	248	353	223	224
Silver ore do	641	641	565	557	587	644
Percentage derived from—						
Dry and siliceous ores	35	37	39	33	33	32
Base-metal ores	65	63	61	67	67	68
Imports, general [1] thousand troy ounces	137,705	60,657	50,256	76,359	59,062	51,674
Refinery production do	34,746	36,800	34,900	36,345	35,000	37,000
Exports [1] do	6,521	26,593	39,828	13,057	31,485	109,395
Stocks Dec. 31: Treasury million troy ounces	2,018	1,992	[r] 1,862	1,767	[r] 1,583	1,218
Consumption—industry and the arts thousand troy ounces	96,660	102,000	105,500	110,400	110,000	120,500
Coinage do	34,215	46,000	55,900	77,368	111,493	203,000
Price per troy ounce	[2] $0.905+	[2] $0.905+	[3] $0.924+	[3] $1.085+	[3] $1.279+	[3] $1.293
World:						
Production thousand troy ounces	228,800	241,300	237,000	243,600	250,800	249,500
Consumption [4]—industry and the arts thousand troy ounces	204,900	224,600	239,500	247,800	252,200	285,900
Coinage do	73,860	103,900	137,100	127,600	167,000	264,500

[r] Revised.
[1] Excludes coinage.
[2] Treasury buying price for newly mined silver.
[3] Average New York price.
[4] Free world only.

DOMESTIC PRODUCTION

Mine output of recoverable silver in the United States increased 3 percent. Production gains in Arizona, Colorado, and Montana, more than offset losses in Idaho, Missouri, Nevada, New Mexico, and Utah. An 8-percent gain in the Arizona silver production resulted largely from greater output of silver-bearing copper ore. About 75 percent of the State's silver production was derived as a byproduct from copper refining; 25 percent was produced from lead-zinc and miscellaneous ores. In Colorado, the 14-percent production gain reflected increased output of copper and miscellaneous copper-zinc-lead ores yielding byproduct or coproduct silver. An increase of nearly 25 percent in the Montana silver output was due chiefly to the sharp gain in copper production of Butte mines from which nearly two-thirds of the total silver output was recovered as a byproduct; zinc ores in the Butte district yielded most of the remainder. Similarly, in New Mexico a 6-percent decrease in silver output came chiefly from copper ores at the Chino and Bonney-Misers Chest mines and from zinc ores at the Kearney mine.

Silver production dropped slightly in Idaho owing to losses at the Sunshine mine which was idled by a labor dispute which began in November 1963 and ended in March 1964. The Nevada silver production dropped 20 percent to an alltime low, owing chiefly to inactivity at the Copper Canyon mine where silver was recovered as a byproduct, the closing of a tailings treatment plant, and curtailed production at the Bristol silver and Tempiute mines. A 5-percent falloff in Utah silver production was attributed largely to decreased production of silver ore and to a lesser extent to the decline in output of silver-bearing copper ore owing to a shutdown at the Utah Copper mine because of a labor strike.

Idaho, the leading silver-producing State, contributed 45 percent of the total domestic silver output. The four leading silver-producing States, Idaho, Arizona, Montana, and Utah, supplied 88 percent of the total output.

Two-thirds of the total domestic silver output was recovered as a byproduct of ores mined chiefly for copper, lead, zinc, and gold; virtually all of the remainder came from ores in which silver was the principal product. Of the 25 leading silver-producing mines, only 4 in Idaho depended chiefly on the value of silver in the ore. Nine mines produced over 1 million ounces each and supplied 60 percent of the total domestic output; the 25 leading mines furnished 84 percent. Domestic mines supplied nearly 30 percent of the silver used in the Nation's arts and industries.

The Sunshine mine, the Nation's leading silver producer, recovered 2.6 million ounces of silver, compared with 2.8 million ounces in 1963. The mine was closed for 2⅓ months of the year because of a labor strike. Tons of ore milled declined slightly, and average grade of ore declined from 38.2 to 36.0 ounces per ton. Ore reserves at the four areas comprising the Sunshine operation totaled 424,900 tons at yearend, compared with 457,700 tons at the end of 1963.[2]

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[2] Sunshine Mining Co. Annual Report 1964. Mar. 31, 1965, 8 pp.

The Lucky Friday mine of the Hecla Mining Co. treated 182,700 tons of ore averaging 19.4 ounces of silver per ton in addition to lead and zinc. The ore reserve at yearend was estimated at 691,000 tons, compared with 767,000 tons in 1963.[3]

Exploration and development of silver-bearing deposits continued at a high level especially in Idaho, Nevada, and Utah; several additional mines and prospects that had been closed were reactivated, and a few beneficiation plants were under construction.

Although detailed data on sources are not available, a substantial quantity of secondary silver was recovered by refiners from photographic and electroplating wastes, discarded jewelry and silverware, and other scrap materials. In addition, silver was recovered from wornout coins and returned to monetary use by the U.S. Treasury. According to data compiled by the Bureau of the Mint, 76 million ounces of secondary silver was returned from industrial and monetary use for re-refining and reuse.

Approximately 920 persons were employed in the silver-mining industry at 70 mine operations.

Terminology and definitions used in classifying silver-bearing ores follow:

Copper ores include smelting ores that contain 2.5 percent or more recoverable copper and ores and tailings concentrated or leached chiefly for their copper content. Ores leached in place or ores for which the tonnage cannot be calculated are excluded; slags smelted for their copper content are included.

Lead ores are those that contain 5 percent or more recoverable lead, irrespective of the precious metal content, and ores, tailings, or slags that are treated chiefly for their lead content.

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[3] Hecla Mining Co. Sixty-Seventh Annual Report. 1964, p. 9.

Zinc-concentrating ores and tailings include those from which a marketable zinc concentrate is made, irrespective of precious metal content. Virtually no zinc ore is now smelted directly except for cold slags, which when fumed are classified as smelting ore and may contain as little as 5 percent recoverable zinc.

The mixed ores are combinations of the foregoing ores; they will be designated by the names of their constituent base metals in alphabetical order, irrespective of the predominance of value.

Gold, gold-silver, and silver ores with the base-metal content too small to be classified in accordance with the foregoing are dry ores, irrespective of the ratio of concentration. The dry ores are thus ores, chiefly siliceous, valuable for their silver and gold content, and in some instances for their fluxing properties, regardless of method of treatment. Dry gold ores are defined as those in which the gold value equals or exceeds three-fourths of the combined gold and silver values; dry silver ores are those in which the silver value equals or exceeds three-fourths of the combined gold and silver values. The gold and silver values in dry gold silver ores equal or exceed one-fourth of the combined gold and silver values. Tailings and slags follow the same scheme of classification as ores.

The classifications are not to be modified by considerations of payments of metals by smelters or customs mills, or by method of treatment by the smelters.

TABLE 2.—Mine production of silver in the United States in 1964, by months

Month	Thousand troy ounces	Month	Thousand troy ounces
January	2,651	August	2,897
February	2,465	September	3,032
March	2,892	October	3,234
April	3,257	November	3,076
May	3,303	December	3,223
June	3,376		
July	2,928	Total	36,334

TABLE 3.—Twenty-five leading silver-producing mines in the United States in 1964, in order of output

Rank	Mine	District or region	State	Operator	Source of silver
1	Sunshine	Evolution	Idaho	Sunshine Mining Co	Silver ore.
2	Galena	Placer Center	do	American Smelting and Refining Company	Do.
3	Lucky Friday	Hunter	do	Hecla Mining Co	Lead ore.
4	Butte Hill Copper Mines	Summit Valley	Montana	The Anaconda Company	Copper ore.
5	Utah Copper	West Mountain	Utah	Kennecott Copper Corp	Copper, gold-silver ores.
6	Bunker Hill	Yreka	Idaho	The Bunker Hill Co	Lead-zinc ore.
7	Berkeley Pit	Summit Valley	Montana	The Anaconda Company	Copper ore.
8	Butte Hill Zinc Mines	do	do	do	Zinc ore.
9	United States and Lark	West Mountain	Utah	United States Smelting Refining, and Mining Co	Lead-zinc, lead ores.
10	Mission	Pima	Arizona	American Smelting and Refining Company	Copper ore.
11	Copper Queen-Lavender Pit	Warren	do	Phelps Dodge Corp	Do.
12	Iron King	Big Bug	do	Shattuck Denn Mining Corp	Lead-zinc ore.
13	Eagle	Red Cliff	Colorado	The New Jersey Zinc Co	Copper, zinc ores.
14	Idarado	Red Mountain-Upper San Miguel	do	Idarado Mining Co	Copper, lead-zinc ores.
15	New Cornelia	Ajo	Arizona	Phelps Dodge Corp	Copper, gold-silver ores.
16	Star-Morning Unit	Hunter	Idaho	The Bunker Hill Co. and Hecla Mining Co	Lead-zinc ore.
17	Crescent	Yreka	do	The Bunker Hill Co	Silver ore.
18	Keystone	Elk Mountain	Colorado	McFarland and Hullinger	Copper, lead-zinc ores.
19	Morenci	Copper Mountain	Arizona	Phelps Dodge Corp	Copper, gold-silver ores.
20	Page	Yreka	Idaho	American Smelting and Refining Company	Lead-zinc ore.
21	Pima	Pima	Arizona	Pima Mining Co	Copper ore.
22	Mayflower Unit	Blue Ledge	Utah	Hecla Mining Co	Lead-zinc ore.
23	United Park City	Uintah-Blue Ledge	do	United Park City Mines Co	Do.
24	Silver Summit	Evolution	Idaho	Hecla Mining Co	Silver ore.
25	Magma	Pioneer	Arizona	Magma Copper Co	Copper, gold-silver ores.

TABLE 4.—Production of silver in 1962–64 in the United States by States, and by source 1964

State	1962	1963	1964 by type of mine production						Refinery production [1]
			Placers	Dry ore	Copper ore	Lead and zinc ores	Complex base metal ores	Total	
Alaska	22,199	14,010	6,538	474	324	-----	-----	7,336	7,300
Arizona	5,453,585	5,373,058	1	26,119	4,917,186	27,340	817,104	[2] 5,810,510	6,000,000
California	132,505	156,528	3,636	13,842	25	40,561	45,413	[3] 171,621	179,550
Colorado	2,087,813	2,307,305	152	161,116	472,746	295,631	1,696,786	2,626,431	2,707,000
Idaho	17,772,435	16,710,725	21	10,208,754	6,075	3,564,674	2,703,971	16,483,495	16,628,000
Illinois	-----	-----	-----	-----	-----	-----	-----	-----	15,000
Kentucky	1,410	1,515	-----	-----	-----	-----	-----	[4] 1,673	1,800
Michigan	401,491	338,997	-----	-----	349,195	-----	-----	349,195	306,550
Missouri	490,896	131,664	-----	-----	-----	-----	-----	-----	5,220
Montana	4,560,714	4,241,620	28	637,965	3,312,067	1,335,691	4,208	5,289,959	5,500,000
Nevada	245,164	214,976	171	43,269	103,337	25,670	-----	172,447	125,100
New Mexico	301,549	256,475	-----	30,421	104,744	75,329	31,911	242,405	250,000
New York	19,451	19,544	-----	-----	-----	-----	13,306	13,306	14,000
North Carolina	100,439	26,754	-----	-----	-----	-----	-----	-----	4,700
Oregon	6,047	58,234	45	14,256	71	-----	-----	14,372	30,400
Pennsylvania	(5)	(5)	-----	(5)	(5)	(5)	(5)	(5)	(5)
South Dakota	113,052	117,301	-----	132,981	-----	-----	-----	132,981	131,700
Tennessee	112,251	107,913	-----	-----	-----	-----	90,539	90,539	90,900
Texas	-----	-----	-----	-----	-----	-----	-----	-----	950
Utah	4,628,446	4,790,511	-----	144,977	2,116,401	87,870	2,198,416	[2] 4,551,960	4,600,000
Virginia	-----	-----	-----	-----	-----	-----	-----	-----	369
Washington	350,185	374,373	-----	331,464	-----	4,845	28,766	[6] 375,603	390,000
Wisconsin	-----	-----	-----	-----	-----	-----	-----	-----	11,460
Wyoming	-----	-----	-----	-----	28	-----	-----	28	1
Total	36,799,632	35,241,503	10,592	11,745,638	11,382,199	5,457,611	7,630,420	36,333,861	37,000,000
Percent [7]	-----	-----	(8)	33	31	15	21	100	-----

[1] U.S. Bureau of the Mint.
[2] Includes byproduct silver from uranium ore.
[3] Includes byproduct silver from tungsten ore.
[4] Calcium fluorite.
[5] Included with Washington.
[6] Includes silver from magnetite-pyrite ore in Pennsylvania.
[7] Percentage based on total, excluding 107,401 ounces obtained from other ores.
[8] Less than 0.5 percent.

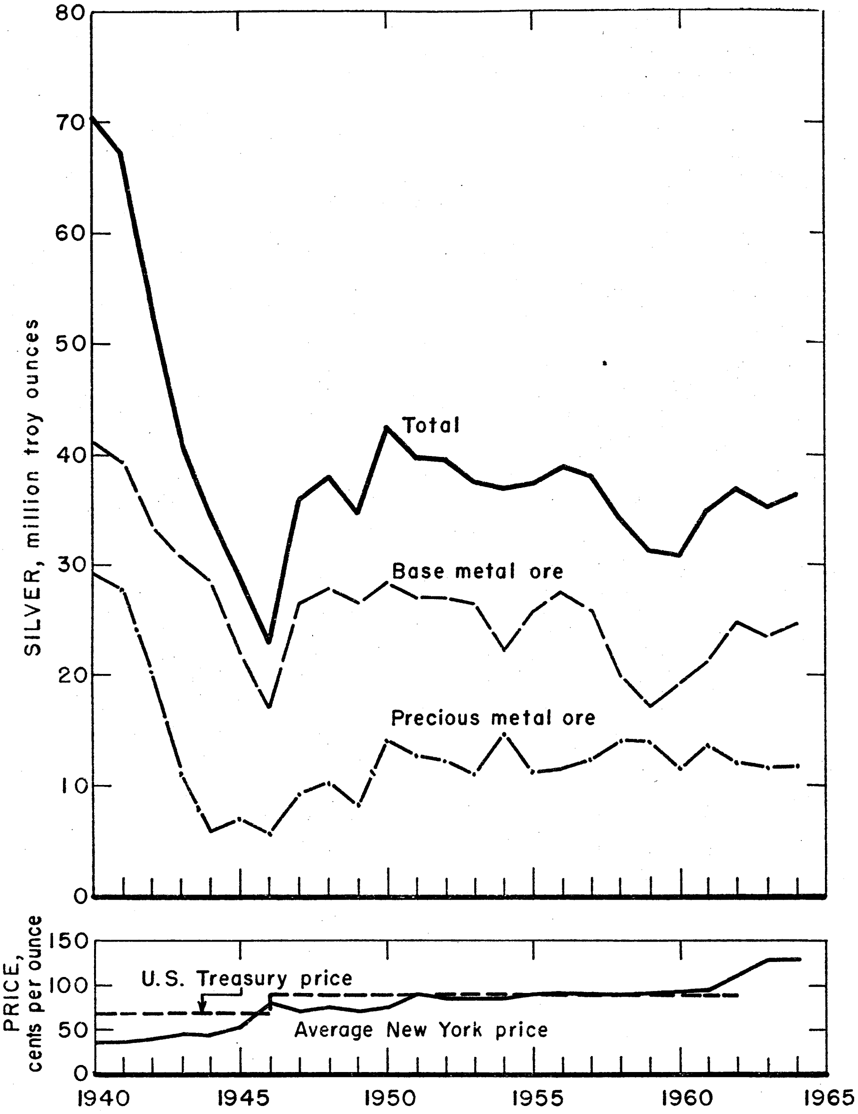

FIGURE 1.—Silver production in the United States and price per ounce.

CONSUMPTION AND USES

Consumption of silver in the arts and industries of the United States was 121 million ounces, 10 percent more than in 1963, according to data compiled by the Bureau of the Mint. This was 15 percent above the average for the preceding 5 years. Imports and mine production furnished nearly three-fourths of the total industrial and defense requirements; the remainder was supplied from Treasury stocks and secondary production.

The use of silver increased in all major industrial categories. Although detailed data on end-use consumption of silver were incomplete, it was estimated that silver use increased as follows: In photographic materials by about 20 percent to approximately 35 million ounces; for silverware and jewelry substantially to about 23 million ounces; for electrical and electronic uses by about 15 percent to 30 million ounces; for brazing alloys and solders moderately to about 16 million ounces; and for battery manufacture sharply to about 9 million ounces.

The quantity of silver used in minting subsidiary coins increased sharply to 203 million ounces, 92 million ounces more than in 1963. About 201 million Kennedy half dollars were minted, using about 72.7 million ounces of silver, or nearly 36 percent of all silver used in subsidiary coins. U.S. coinage requirements constituted three-fourths of the total silver used in free-world coinage. The 1964 gain was the sixth consecutive annual increase and was attributed primarily to the continued growth in the use of coin-operated vending and metering machines and the withdrawal of coins from circulation by collectors and speculators. It was estimated that more than $3 billion worth of goods was sold through vending machines during the year and that about 30 billion coins were used in these machines.

Applications of silver batteries, which provide maximum output with minimum size and weight and have long life, continued to increase. Silver-zinc batteries were specified to power portable field communications equipment under rugged military service conditions. These batteries in miniature form have been used almost exclusively in missiles and space vehicles. A large silver-zinc storage battery was developed by Electric Storage Battery Co. to power the Reynolds Aluminaut submarine. This battery was said to be the most powerful of its size ever built. In addition, the battery provided power for light, heat, and auxiliary equipment. The use of silver chloride seawater batteries, especially for military applications such as torpedo propulsion, also increased.

In electronics, the use of silver-clad materials for semiconductors increased as advances were made in microelectronics technology. Expanding uses of silver on ceramic materials included conductive coatings for capacitors, and printed circuits on titanates; silver also was used on glass-bonded mica, alumina, and porcelain. These coatings also were used to metallize ceramic parts for sealing enclosures as integral sections of coils and transformers.

Corning Glass Works continued experimental work on photochromic glass utilizing silver halides for controlling optical transmittance of light. Tests indicate that such glass has potential for use in windows, sunglasses, and optical memory and self-erasing display devices, and as "light valves" in many types of optical systems Some properties of photochromic glass were described by S. D. Stookey at the American Physical Society meeting in New York in January 1964.

A silver-coated copper powder was developed to replace more expensive pure silver for electrical contacts and other products. The new material was supplied in five grades ranging from 2.5 to 16 weight-percent silver.

Silver-plated nickel catalyst screens were developed by Bell Aerospace Co. for use in propellant reaction control systems of space vehicles. The catalyst screens decomposed hydrogen peroxide to superheated steam and oxygen. Exhausting these gases through the rocket nozzle provides thrust to control the space vehicle.

A silver-membrane filter with a porosity as low as 0.2 micron was developed by Selas Corp. of America. The new membrane, called Flotronics filter, made by powder metallurgical methods, has biological as well as industrial applications; these include uses in the preparation of critical aerospace components for removal of suspended solids in critical fluids and servomechanisms, hydraulic systems, bearings, and gyroscopes. Pore sizes can be closely controlled for each grade, yet the proportion of open area through which the liquid can flow is relatively large. These properties are attained by controlling the size and shape of the silver particles making up the filter and their orientation during formation of the membrane. The filters are stable in a range between −200° and 700° F and have bacteriostatic action characteristics of silver.

A silver-filled silicone grease which combines electrical conductivity with good lubricating properties at high temperatures was developed by Epoxy Products, Inc. The grease can be used as a conductive lubricant, a nonpermanent electrical connection, or a fluid gasket between mechanically fastened parts.

National Aeronautics and Space Administration researchers developed a molybdenum disulfide-silver motor brush using sintering techniques. Under high-vacuum conditions of space and in all applications where long-wearing qualities were desired, the brush performed without excessive heating for much greater periods than the conventional high-altitude graphite brush.

TABLE 5.—Ore, old tailings, etc., yielding silver produced in the United States, and average recoverable content, in troy ounces of silver per ton in 1964

State	Gold ore		Gold-silver ore		Silver ore		Copper ore	
	Short tons	Average ounces of silver per ton	Short tons	Average ounces of silver per ton	Short tons	Average ounces of silver per ton	Short tons	Average ounces of silver per ton
Alaska	2,476	0.191	------	------	------	------	17	19.059
Arizona	208	1.692	141,246	0.134	19,427	0.352	85,357,352	.058
California	9,672	.094	------	------	580	22.300	19	1.316
Colorado	9,153	1.361	262	29.702	9,786	14.395	34,661	13.639
Idaho	1,338	1.879	3	72.000	395,369	25.814	71,547	.085
Michigan	------	------	------	------	------	------	8,892,340	.039
Montana	897	.681	22,188	9.505	109,930	3.879	13,613,530	.243
Nevada	394,350	.039	60	48.000	20,036	1.253	8,390,161	.012
New Mexico	35	4.571	15,478	1.738	527	6.380	7,221,080	.015
South Dakota	2,032,955	.060	18	612.667	------	------	------	------
Utah	------	------	44,392	.432	87,657	1.435	24,581,312	.086
Undistributed [1]	179,760	1.829	600	4.607	1,134	12.462	125	.792
Total	2,630,844	.184	224,247	1.340	644,446	17.009	148,162,144	.077

State	Lead ore		Zinc ore		Zinc-lead, zinc-copper, and zinc-lead-copper ores		Total ore	
	Short tons	Average ounces of silver per ton	Short tons	Average ounces of silver per ton	Short tons	Average ounces of silver per ton	Short tons	Average ounces of silver per ton
Alaska	------	------	------	------	------	------	2,493	0.320
Arizona	3,184	7.511	15,714	0.218	428,501	1.907	85,965,632	[2] .068
California	1,999	20.291	------	------	3,600	12.615	15,870	[3] 10.585
Colorado	1,320	8.995	294,267	.964	702,053	2.417	1,051,502	2.498
Idaho	211,036	16.736	65,094	.504	904,946	2.988	1,649,333	9.994
Michigan	------	------	------	------	------	------	8,892,340	.039
Montana	6,359	4.640	1,080,743	1.209	226	18.619	14,833,873	.357
Nevada	3,466	6.889	1,491	1.202	------	------	8,809,564	.020
New Mexico	119	3.092	308,857	.243	15,358	2.078	7,561,454	.032
South Dakota	------	------	------	------	------	------	2,032,973	.065
Utah	6,654	11.872	43,609	.204	515,246	4.267	25,278,870	[2] .180
Undistributed [1]	282	.574	186,691	.025	2,824,603	.047	[4] 4,936,440	.100
Total	234,419	15.959	1,996,466	.860	5,394,533	1.414	161,030,344	.226

[1] Includes Kentucky, New York, Oregon, Pennsylvania, Tennessee, Washington, and Wyoming.
[2] Includes byproduct silver from uranium ore.
[3] Includes byproduct silver from tungsten ore.
[4] Includes calcium fluorite in Kentucky and magnetite-pyrite ore in Pennsylvania.

TABLE 6.—Silver produced in the United States from ore and old tailings in 1964, by States and methods of recovery, in terms of recoverable metal

State	Total ore, old tailings, etc., treated (thousand short tons)	Ore and old tailings to mills					Crude ore to smelters	
		Thousand short tons	Recoverable in bullion		Concentrates smelted and recoverable metal			
			Amalgamation (troy ounces)	Cyanidation (troy ounces)	Concentrates (short tons)	Troy ounces	Thousand short tons	Troy ounces
Alaska	2	2	451	--------	--------	--------	(1)	347
Arizona	86,808	86,154	2	--------	2,666,493	5,430,425	653	380,082
California	16	10	842	--------	3,478	70,640	6	96,503
Colorado	1,052	1,028	3,095	--------	156,670	2,100,027	24	523,157
Idaho	1,649	1,594	365	--------	220,475	16,423,657	55	59,452
Michigan	8,892	8,892	--------	--------	201,633	349,195	--------	--------
Montana	14,872	14,718	--------	--------	420,454	4,775,213	154	514,718
Nevada	13,378	13,326	258	15,105	281,273	124,426	52	32,487
New Mexico	7,915	7,811	--------	--------	329,859	210,079	105	32,326
South Dakota	2,033	2,033	86,380	35,573	--------	--------	(1)	11,028
Utah	25,308	25,095	--------	--------	776,739	4,256,376	213	295,584
Undistributed [2]	3,875	3,869	8	70,216	146,720	414,368	6	10,884
Total	165,800	164,532	91,401	120,894	5,203,794	34,154,406	1,268	1,956,568

[1] Less than 0.5 short ton.
[2] Includes Kentucky, New York, Oregon, Pennsylvania, Tennessee, Washington, and Wyoming.

TABLE 7.—Silver produced at amalgamation and cyanidation mills in the United States and percentage of silver recoverable from all sources

Year	Bullion and precipitates recoverable (troy ounces)		Silver from all sources (percent)			
	Amalgamation	Cyanidation	Amalgamation	Cyanidation	Smelting [1]	Placers
1955-59 (average)	91,441	417,022	0.3	1.2	98.4	0.1
1960	86,353	533,286	.3	1.7	97.9	.1
1961	90,527	214,956	.3	.6	99.0	.1
1962	89,203	101,887	.2	.3	99.4	.1
1963	89,777	99,289	.2	.3	99.4	.1
1964	91,401	120,894	.3	.3	99.3	.1

[1] Crude ores and concentrates.

TABLE 8.—Consumption of silver in industry and the arts

(Thousand troy ounces)

Year	Issued for industrial use	Returned from industrial use [1]	Net industrial consumption	Year	Issued for industrial use	Returned from industrial use [1]	Net industrial consumption
1955-59 (average)	130,352	33,692	96,660	1962	180,812	70,412	110,400
1960	151,007	49,007	102,000	1963	204,490	94,490	110,000
1961	155,812	50,312	105,500	1964	196,600	76,100	120,500

[1] Includes secondary materials to monetary use, jewelry, plate, scrap film, and other forms of scrap.

Source: Bureau of the Mint.

STOCKS

Continued heavy withdrawals reduced Treasury stocks of bullion and coin by 364.5 million ounces. The withdrawals comprised 203.0 million ounces for minting subsidiary coins, 19.8 million ounces sold as silver dollars, 141 million ounces issued to commercial consumers in exchange for silver certificates, and sales of 8.9 million ounces, largely to other Government agencies. The falloff in stocks was partly balanced by the growth in coinage in circulation which increased 213.8 million ounces. Silver received by the Treasury, including purchases at market value, coins withdrawn for recoinage, and silver from lend-lease returns, totaled about 1.2 million ounces.

Although part of the 141 million ounces of silver redeemed for commercial use went into consumer stocks, data on the total quantity of silver held in industrial stocks were not available. Stocks of silver held in Commodity Exchange warehouses at yearend totaled 2.50 million ounces, compared with 450,000 ounces at the end of 1963.

The ratio of the value of silver to the total value of gold and silver in the U.S. monetary stocks at yearend was 20.9 percent compared with 21.6 at the end of 1963.

A small quantity of World War II lend-lease silver was due from Pakistan.

TABLE 9.—U.S. monetary silver

(Million troy ounces)

	1960	1961	1962	1963	1964
In Treasury:					
Securing silver certificates:					
Silver bullion	1,741.8	1,730.5	1,654.5	1,532.5	1,190.3
Silver dollars	124.9	100.7	72.7	22.1	2.3
Subsidiary coin	2.0	2.6	2.4	r 2.7	7.5
Free silver bullion	123.5	28.5	37.0	25.2	17.9
Total	1,992.2	r 1,862.3	1,766.6	r 1,582.5	1,218.0
Coinage in circulation:					
Silver dollars	252.5	276.4	303.6	352.9	372.6
Subsidiary coin	1,140.0	1,194.0	1,270.3	r 1,365.2	1,559.3
Total	1,392.5	1,470.4	1,573.9	r 1,718.1	1,931.9
Grand total	3,384.7	3,332.7	3,340.5	3,300.6	3,149.9

r Revised.

Source: U.S. Treasury Department Statements.

PRICES

The price of silver for prompt delivery at New York remained unchanged at 129.3 cents per troy ounce in 1964, the first full year of a stable silver price since 1960. The stability in the New York price reflected the availability of silver from the Treasury through the redemption of silver certificates which provided an effective price ceiling at the monetary price.

Prices on the New York Commodity Exchange for future delivery, unlike the stable price for prompt delivery, reached new highs during the year. About 104 million ounces were traded at prices ranging from 128.5 to 138.5 cents per ounce. At yearend, open contracts for 30 million ounces were outstanding.

The price ratio of gold to silver was 27 to 1 with gold at $35 and silver at $1.293 per ounce.

In the London market, the spot price of silver showed little change, except for minor fluctuations due to the influence of sterling-dollar exchange rates. Prices ranged from 111.625d in May to an alltime high of 112.25d in September, approximately equivalent to 130.228 and 130.956 cents, respectively. The average price for the year was 111.923d, equivalent to 103.578 cents.

London dealers bought silver from the U.S. monetary stock during the year. Prices for 2-month delivery ranged from 111.625d(130.228 cents) in the first quarter to 113.500d (132.416 cents) in December. Trading was active and purchases heavy in the last quarter, owing chiefly to consumer hedging and speculation regarding a possible higher price in the United States and to some extent to fears of devaluation of the pound.[4]

FOREIGN TRADE

The United States became a net exporter of silver for the first time since lend-lease shipments of World War II.

The value of net imports for the period 1955–64 was as follows:

	Net Imports (thousands)	*Net Exports (thousands)*
1955–59 (average)	$103, 647	---------
1960	29, 459	---------
1961	8, 047	---------
1962	59, 346	---------
1963	27, 259	---------
1964	--------	$77, 002

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[4] Samuel Montagu & Co., Ltd. Annual Bullion Review, 1964. February 1965, pp. 14–15.

TABLE 10.—U.S. imports of silver in 1964, by countries

Country	Ore and base bullion		Refined bullion		U.S. coin value	Foreign coin value
	Troy ounces	Value	Troy ounces	Value		
North America:						
Bahamas	----	----	----	----	$5,000	----
Bermuda	----	----	----	----	----	$304
Canada	20,647,620	$26,226,794	----	----	1,690	50,898
El Salvador	2,082	2,683	----	----	----	----
Guatemala	9,445	12,011	----	----	----	----
Haiti	----	----	----	----	200,000	----
Honduras	2,951,834	3,603,896	----	----	----	----
Mexico	3,642,714	4,618,931	5,094,907	$5,743,680	25,000	1,252,014
Netherlands Antilles	----	----	----	----	----	5,700
Nicaragua	142,622	170,743	----	----	----	----
Panama	30	38	----	----	825	8,400
Total	27,396,347	34,635,096	5,094,907	5,743,680	232,515	1,317,316
South America:						
Bolivia	3,106,654	3,956,522	----	----	----	----
Chile	1,982,607	2,332,514	----	----	----	----
Colombia	17,722	22,861	----	----	----	----
Ecuador	50,892	63,663	----	----	----	----
Peru	7,667,932	9,626,229	3,255,109	4,183,913	----	----
Total	12,825,807	16,001,789	3,255,109	4,183,913	----	----
Europe:						
Austria	----	----	----	----	471	----
Denmark	----	----	----	----	218	----
France	----	----	67,195	87,017	----	1,258
Germany, West	237	305	----	----	4,765	4,524
Ireland	----	----	----	----	5,000	----
Italy	----	----	----	----	----	10,786
Norway	6,400	8,128	----	----	----	1,706
Switzerland	----	----	----	----	----	8,946
U.S.S.R.	----	----	----	----	124,645	----
United Kingdom	89,300	79,850	933	1,210	55,823	23,386
Yugoslavia	----	----	96,452	127,314	----	----
Total	95,937	88,283	164,580	215,541	190,922	50,606
Asia:						
Iran	----	----	----	----	----	3,999
Israel	5,796	6,873	----	----	5,003	4,715
Japan	----	----	----	----	14,358	14,654
Korea, South	59,055	74,657	----	----	----	----
Philippines	351,708	431,655	12,933	16,271	76,130	----
Turkey	2,475	3,204	----	----	----	2,300
Total	419,034	516,389	12,933	16,271	95,491	25,668
Africa:						
Algeria	19,258	24,843	----	----	----	----
Kenya	514	665	----	----	----	----
Mozambique	9,952	9,454	----	----	----	----
Rhodesia and Malawi	11,198	10,638	----	----	----	----
South Africa, Republic of	717,652	892,364	----	----	----	----
United Arab Republic (Egypt)	----	----	----	----	----	4,086
Total	758,574	937,964	----	----	----	4,086
Oceania: Australia	1,650,728	2,055,799	----	----	----	----
Grand total	43,146,427	54,235,320	8,527,529	10,159,405	518,928	1,397,676

Source: Bureau of the Census.

TABLE 11.—U.S. exports of silver in 1964, by countries

Destination	Ore and base bullion		Refined bullion		U.S. coin value	Foreign coin value
	Troy ounces	Value	Troy ounces	Value		
North America:						
Bahamas	----------	----------	----------	----------	$40,500	----------
Canada	74,152	$95,874	4,719,069	$6,111,945	6,566	$1,068,381
Netherlands Antilles	----------	----------	----------	----------	11,150	----------
Panama	----------	----------	----------	----------	150	----------
Total	74,152	95,874	4,719,069	6,111,945	58,366	1,068,381
South America:						
Argentina	----------	----------	----------	----------	600	----------
Colombia	----------	----------	5,363	6,933	----------	----------
Uruguay	----------	----------	11,740	15,144	----------	----------
Venezuela	----------	----------	2,250	2,962	----------	1,260
Total	----------	----------	19,353	25,039	600	1,260
Europe:						
Austria	----------	----------	----------	----------	100	----------
Belgium-Luxembourg	348,569	452,190	1,196,935	1,547,592	250	----------
Czechoslovakia	----------	----------	----------	----------	2,700	----------
France	----------	----------	15,480,548	20,020,030	900	----------
Germany, West	146,634	189,013	10,612,523	13,696,138	7,227	----------
Ireland	----------	----------	----------	----------	17,200	----------
Italy	----------	----------	3,276,689	4,236,557	3,225	1,485,078
Netherlands	----------	----------	1,034,581	1,342,533	20,000	----------
Sweden	----------	----------	----------	----------	350	----------
Switzerland	2,027,521	2,620,477	10,463,319	13,526,485	40,908	----------
United Kingdom	79,329	102,453	52,813,535	68,243,806	----------	----------
Total	2,602,053	3,364,133	94,878,130	122,613,141	92,860	1,485,078
Asia:						
Israel	----------	----------	----------	----------	5,400	----------
Japan	----------	----------	6,618,766	8,560,177	----------	----------
Nansei and Nanpo Islands	----------	----------	----------	----------	12,192	----------
Thailand	----------	----------	482,177	624,900	----------	----------
Total	----------	----------	7,100,943	9,185,077	17,592	----------
Oceania: Australia	----------	----------	1,000	1,513	----------	----------
Grand total	2,676,205	3,460,007	106,718,495	137,936,715	169,418	2,554,719

Source: Bureau of the Census.

TABLE 12.—Value of silver imported into and exported from the United States

(Thousand dollars)

Year	Imports	Exports
1955–59 (average)	$109,622	$5,975
1960	53,961	24,502
1961	45,005	36,958
1962	72,721	13,375
1963	67,281	40,022
1964	64,394	141,397

Source: Bureau of the Census.

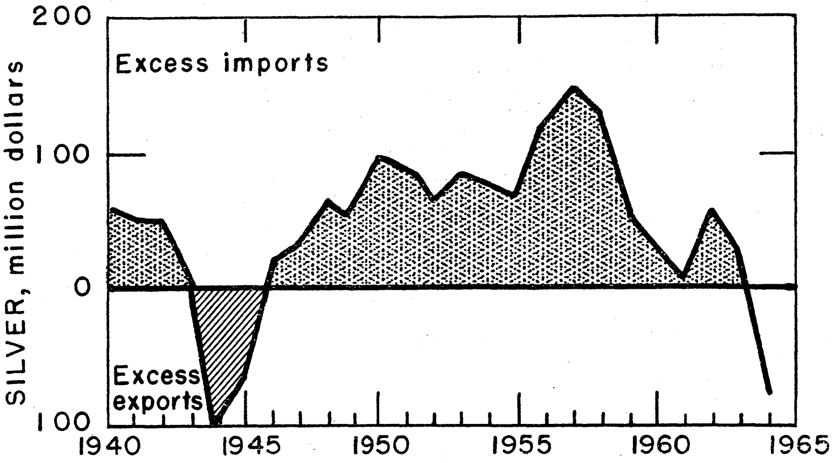

Figure 2.—Net imports or exports of silver.

WORLD REVIEW

World silver output was estimated at 249.5 million ounces, about 1.3 million ounces less than in 1963. Production gains in Canada, Peru, and the United States, failed to offset declines in production in Mexico, Honduras, Australia, and Japan. Changes in silver output of other countries were small. Mexico, Peru, the United States, and Canada, the four leading silver producers, contributed about 58 percent of the world output.

Total consumption of silver in the arts and industries and coinage of the free world was estimated at 550.4 million ounces. The quantity of silver consumed for industrial use was 285.9 million ounces, 33.7 million ounces more than in 1963, but coinage requirements aggregated 264.5 million ounces, 58 percent greater than in 1963.[5] The gain in overall coinage consumption of silver was due chiefly to increased demand for subsidiary coins in the United States. Coinage requirements also increased in Canada, Italy, and Japan, but declined in France and most other free world countries. The sharp increase in coinage consumption of silver in Japan resulted from the special coinage program for the Olympic Games.

Consumption of silver in free world countries continued to exceed mine production by a substantial margin, and in 1964 the excess rose to nearly 337 million ounces. Excluding U.S. coinage requirements, which were not part of the market demand, the production deficit amounted to about 132 million ounces and was balanced chiefly by withdrawals from U.S. Treasury stocks which supplied 151 million ounces. Stocks of foreign governments furnished 20 million ounces, demonetized coin supplied 20 million ounces, and salvage and miscellaneous sources accounted for about 11.4 million ounces.[6]

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[5] Handy & Harman. The Silver Market in 1964. P. 19.

[6] Page 20 of work cited in footnote 5.

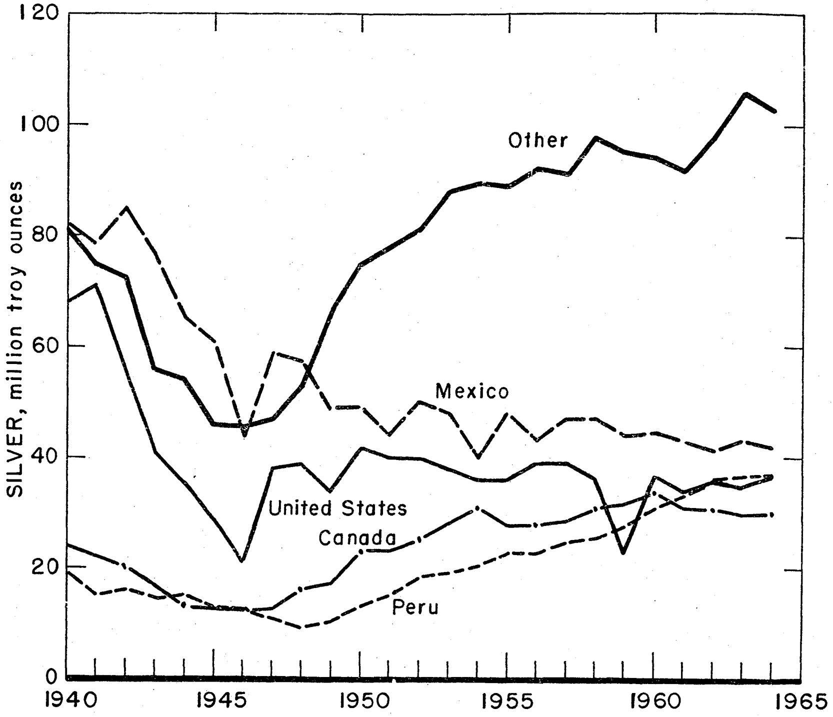

FIGURE 3.—World production of silver.

TABLE 13.—World production of silver, by countries [1] [2] [3]

(Troy ounces)

Country	1955–59 (average)	1960	1961	1962	1963	1964 [p]
North America:						
Canada	29,665,358	34,016,829	31,381,977	30,669,028	29,839,756	30,316,486
Central America and West Indies:						
Cuba (U.S. imports)	253,787	121,415	------------	------------	------------	------------
El Salvador	192,109	76,809	------------	------------	------------	------------
Guatemala	362,669	[4] 663,121	[4] 515,905	[e] 32,400	[e] 64,200	[5] 9,445
Haiti	------------	[e] 19,600	61,424	94,761	107,022	[e] 93,700
Honduras	2,403,629	2,948,341	3,544,702	3,179,653	[6] 4,280,746	3,220,371
Nicaragua	271,922	326,673	417,253	500,050	405,252	332,370
Mexico	45,970,571	44,526,463	40,349,181	41,249,402	42,760,487	41,943,247
United States [7]	34,745,842	36,800,000	34,900,000	36,345,000	35,000,000	37,000,000
Total	113,865,900	119,499,300	111,170,400	112,070,300	112,457,500	112,915,600
South America:						
Argentina	1,505,920	1,671,838	1,430,675	2,086,101	1,935,860	1,944,509
Bolivia (exports)	5,865,782	4,887,138	3,901,203	3,759,193	4,854,762	4,822,611
Brazil	214,053	252,930	231,936	250,004	339,448	[e] 200,000
Chile	1,814,781	1,679,105	2,156,768	2,275,887	2,768,340	3,047,679
Colombia	107,420	134,333	127,943	131,599	103,279	130,353
Ecuador	81,630	126,419	101,190	127,739	121,784	117,126
Peru (recoverable)	24,781,843	30,755,496	34,161,707	32,930,783	36,800,350	37,043,217
Total	34,370,000	39,510,000	42,110,000	41,560,000	46,930,000	47,300,000
Europe:						
Austria	12,860	58,193	58,193	68,481	68,803	73,947
Czechoslovakia [8]	1,608,000	1,608,000	1,608,000	1,608,000	1,608,000	1,608,000
Finland	400,013	390,374	456,155	380,495	579,967	607,906
France	717,708	1,039,851	1,128,523	898,977	730,111	[9] 730,111

See footnotes at end of table.

TABLE 13.—World production of silver, by countries [1] [2] [3]—Continued

(Troy ounces)

Country	1955-59 (average)	1960	1961	1962	1963	1964 [p]
Europe—Continued						
Germany:						
East [8]	4,800,000	4,800,000	4,800,000	4,800,000	4,800,000	4,800,000
West	2,137,652	1,839,247	1,879,436	1,925,701	2,067,325	1,990,935
Greece	100,021	105,487	113,396	138,248	157,539	[9] 157,539
Hungary [8]	64,300	64,300	64,300	64,300	64,300	64,300
Italy	1,049,683	943,946	973,139	929,832	1,006,318	1,060,974
Norway	37,938	-----	-----	-----	-----	-----
Poland [8]	128,600	128,600	128,600	128,600	128,600	128,600
Portugal	55,736	52,920	48,258	52,920	48,419	48,775
Rumania [8]	643,000	643,000	643,000	643,000	643,000	643,000
Spain	1,635,528	1,739,677	4,526,599	5,684,123	4,955,201	[9] 4,955,201
Sweden	2,702,945	2,756,026	2,949,766	3,367,276	3,582,200	3,060,751
U.S.S.R. [e]	25,000,000	25,000,000	25,000,000	27,000,000	27,000,000	27,000,000
United Kingdom	23,766	7,098	4,744	514	-----	-----
Yugoslavia	2,982,476	3,025,160	3,454,083	3,750,931	3,791,923	4,036,879
Total [e]	44,100,000	44,200,000	47,800,000	51,400,000	51,200,000	51,000,000
Asia:						
Burma	1,713,585	1,984,263	1,743,302	1,940,037	2,076,938	1,355,000
China [8]	572,000	800,000	800,000	800,000	800,000	800,000
India	123,796	132,718	191,008	138,698	128,314	152,204
Indonesia	[10] 185,981	310,512	324,079	248,236	279,840	[e] 262,100
Japan	6,372,445	6,912,602	7,960,202	8,660,510	8,812,068	8,625,337
Korea:						
North [e]	286,000	500,000	640,000	640,000	640,000	640,000
South	208,609	329,649	460,341	412,912	444,002	404,456
Philippines	504,905	1,133,343	812,793	675,570	774,917	851,814
Taiwan	62,832	52,579	77,303	80,129	61,440	60,633
Total [e]	10,000,000	12,200,000	13,000,000	13,600,000	14,000,000	13,200,000
Africa:						
Algeria (recoverable) [11]	263,000	300,000	300,000	275,000	275,000	275,000
Bechuanaland	105	24	39	33	21	1
Congo, Republic of the (Léopoldville)	3,895,037	3,962,836	3,457,877	1,595,513	1,097,176	1,480,252
Ghana (exports)	31,173	14,160	7,027	4,443	4,827	[9] 4,827
Kenya	34,015	35,797	40,731	50,160	52,422	47,702
Morocco	2,117,130	1,097,273	907,905	826,338	772,743	604,080
Rhodesia (formerly Southern)	164,293	392,026	106,801	83,540	83,742	88,463
South Africa, Republic of	1,728,650	2,226,204	2,288,279	2,549,206	2,736,868	2,916,660
South-West Africa, (recoverable)	1,677,554	1,004,921	1,833,437	1,253,200	634,134	328,808
Sudan	-----	-----	-----	-----	-----	40
Swaziland	-----	58	103	132	120	130
Tanzania (exports)	540,404	614,279	64,144	23,959	22,669	25,329
Tunisia	94,060	34,401	69,767	24,615	9,131	12,635
Uganda (exports)	47	109	70	38	9	-----
Zambia [12]	607,863	920,601	738,558	697,054	883,681	977,978
Total	11,150,000	10,600,000	9,810,000	7,380,000	6,570,000	6,760,000
Oceania:						
Australia	15,262,372	15,215,956	13,059,166	17,553,691	19,580,823	18,275,000
Fiji	23,628	31,319	37,712	38,935	46,870	60,564
New Guinea (including Papua)	37,336	33,037	30,242	24,500	23,696	23,199
New Zealand	7,474	1,353	805	416	286	141
Total	15,331,000	15,282,000	13,128,000	17,618,000	19,652,000	18,359,000
World total [e]	228,800,000	241,300,000	237,000,000	243,600,000	250,800,000	249,500,000

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[e] Estimate. [p] Preliminary.

[1] A negligible amount of silver is produced in Bulgaria, Mozambique, Panama, and Turkey, for which countries no estimate has been included in the total.

[2] This table incorporates some revisions. Data do not add exactly to totals shown because of rounding where estimated figures are included in the detail.

[3] Data derived in part from the Yearbook of the American Bureau of Metal Statistics and the 51st annual issue of Metal Statistics (Metallgesellschaft) Germany.

[4] Recoverable.

[5] U.S. imports.

[6] Exports.

[7] Refinery production.

[8] Estimate, according to the 51st annual issue of Metallgesellschaft (Germany) except 1964 which is an extension of the previous year's estimate.

[9] 1963 data.

[10] Average annual production 1957–59.

[11] Estimated recoverable silver content of lead and zinc concentrates, according to the 1963 annual issue of Minerais et Metaux (France) except 1964.

[12] Partially recovered from refinery sludges and blister copper.

Australia.—Mount Isa Mines, Ltd., treated a total of 4.1 million tons of copper and silver-lead-zinc ore and produced 5.9 million ounces of silver, compared with 3.7 million tons and 5.9 million ounces in 1963. Production was sharply reduced in the last 2 months by a labor strike. The ore treatment rate was increased, and construction work on the new 6,000-ton-per-day lead-zinc concentrator advanced. Other related major projects included expansion of the lead smelter and power facilities. The reserve of silver-lead-zinc ore was increased 4.3 million tons to 30.3 million tons containing 5.6 ounces of silver per ton, 7.8 percent lead, and 5.9 percent zinc.

Zinc Corporation, Ltd., treated 806,600 tons of lead-silver ore yielding 2.2 million ounces of silver. Broken Hill South, Ltd., reported milling 300,500 tons of lead-zinc-silver ore yielding about 41,480 tons of lead concentrate containing 38.5 ounces of silver per ton and 47,790 tons of zinc concentrate containing 0.8 ounce of silver per ton. North Broken Hill, Ltd., treated 497,550 tons of lead-zinc-silver ore containing 8.2 ounces of silver per ton.

Canada.—Increased silver production was attributed largely to four new base metal mines which began operations yielding byproduct silver during the year. Three other mines yielding byproduct silver, which had their first full year of operation in 1964, also contributed to the production gain. Increased production in Ontario, Quebec, New Brunswick, Nova Scotia, and Newfoundland more than offset losses in Manitoba, Saskatchewan, and Yukon Territory.

British Columbia, Ontario, and Yukon Territory together continued to supply about two-thirds of the total Canadian silver output. United Keno Hill Mines, Ltd., and Consolidated Mining & Smelting Co. of Canada, Ltd. (Cominco), the two largest silver producers, contributed slightly more than 40 percent of the total silver production.

Exports of refined silver and silver in ores and concentrates aggregated 20.1 million ounces, compared with 19.1 million ounces in 1963. Of the total exports, all but 3.3 million ounces went to the United States. Imports of silver dropped 2.7 million ounces to 5.2 million ounces, virtually all of which came from the United States.

Consumption of silver for industrial use was estimated at 4.8 million ounces, slightly more than in 1963. About 13.7 million ounces was used for coinage, a small increase over the 1963 figure.

United Keno Hill Mines, Ltd., the largest mine producer, reported output of silver was 6.0 million ounces in the fiscal year ending September 30, a slight increase over output in 1963. Ore reserves decreased to 459,000 tons with an average grade of 34.6 ounces of silver per ton, 6.9 percent lead, and 6.2 percent zinc, compared with 494,000 tons averaging 34.6 ounces of silver per ton, 6.6 percent lead, and 5.5 percent zinc in 1963.

The Consolidated Mining & Smelting Co. of Canada reported production of 7.3 million ounces of silver of which 52 percent came from company mines, compared with 6.8 million ounces and 74 percent in 1963. Nearly all of the silver from company mines was recovered as a byproduct of lead-zinc ores from the Sullivan and Bluebell mines.

Texas Gulf Sulphur Co. discovered a large zinc-copper-silver deposit early in 1964 near Timmins, Ontario. Subsequent drilling exploration outlined an ore body estimated to contain more than

55 million tons averaging 7.08 percent zinc, 1.33 percent copper, and 4.85 ounces of silver per ton. A 13-mile access road was built and plans were completed for the construction of a concentrator with an initial capacity of 6,000 tons per day to begin production in 1966.

TABLE 14.—Canada: Geographical distribution of silver production

(Troy ounces)

Province or territory	1963	1964 [p]
Alberta	12	4
British Columbia	6,451,158	5,309,486
Manitoba	766,434	706,296
New Brunswick	332,472	1,478,231
Newfoundland	981,005	1,338,901
Northwest Territories	77,468	61,792
Nova Scotia	423,189	539,801
Ontario	9,601,621	10,719,539
Quebec	4,441,644	4,757,251
Saskatchewan	746,683	611,475
Yukon Territory	6,106,037	5,589,167
Total	29,927,723	31,111,943

[p] Preliminary.

Source: Dominion Bureau of Statistics.

Honduras.—Output of silver was estimated at 3.2 million ounces, about 1.0 million ounces less than in 1963. New York and Honduras Rosario Mining Co. reported that its El Mochito mine produced 3.1 million ounces of silver compared with 2.9 million ounces in 1964. Tonnage milled increased 5 percent but average ore grade declined slightly to 24.8 ounces per ton. Mill recovery of silver was up 2.2 percent to about 91 percent. The company reported ore reserves at yearend were 1.0 million tons averaging 19.2 ounces of silver per ton, 0.02 ounces of gold, 7.9 percent lead, and 7.8 percent zinc. Total silver content of reserves was 19.5 million ounces.[7]

Japan.—Industrial consumption of silver was about 20 million ounces, the same as in 1963. Requirements for coinage were 16.3 million ounces, about 11.3 million ounces more than in 1963. The sharp rise in coinage silver requirements was attributed to the minting of special commemorative coins for the 1964 Olympic Games held in Tokyo. About 80 percent of the total silver used in coinage was obtained from government stocks; the remainder came from domestic production and imports. About 6.6 million ounces was imported from the United States. Government silver stocks at yearend were estimated at 23.5 million ounces, compared with 32 million ounces in 1963.[8]

Mexico.—Industrial consumption increased 0.8 million ounces to 4.0 million ounces, and about 0.8 million ounces was used in minting 1-peso coins from a 10-percent-silver alloy.

Exports of silver bullion dropped 27 percent to 29.5 million ounces, more than 90 percent was shipped to West Germany and the United States.

About 0.5 million ounces was recovered from demonetized coin, compared with 2.7 million ounces so recovered in 1963. Government stocks at yearend were estimated at 14.0 million ounces, and it was estimated that 60 to 65 million ounces in demonetized coin was still held by the public.[9]

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[7] New York and Honduras Rosario Mining Company. 84th Annual Report. 1964, pp. 14 and 20.

[8] Page 15 of work cited in footnote 5.

San Francisco Mines of Mexico, Ltd., reported production of 3.4 million ounces of silver. About 765,000 tons of ore were milled averaging about 5.4 ounces of silver per ton, 0.014 ounce gold, 4.7 percent lead, 0.58 percent copper, and 7.4 percent zinc.

Development work at the San Francisco and Clarines mines totaled 4,100 feet. Drift footage was 2,900 of which about 32 percent was in ore. Ore reserves dropped 4 percent to 6.5 million tons averaging 5.2 ounces per ton silver, 0.014 ounce gold, 5.3 percent lead, 0.53 percent copper, and 7.7 percent zinc.[10]

The Fresnillo Co. reported that the Fesnillo unit in the State of Zacatecas produced 2.77 million ounces of silver from the treatment of 586,180 tons of ore averaging 6.0 ounces of silver per ton, 0.024 ounce gold, 2.4 percent lead, 3.7 percent zinc, and 0.25 percent copper. The Naica unit in the State of Chichuahua produced 2.74 million ounces of silver from milling 518,840 tons of ore averaging 6.0 ounces of silver per ton, 0.011 ounce of gold, 6.8 percent lead, 5.5 percent zinc, and 0.35 percent copper.[11]

Operating costs per ton of ore milled were $10.62 at the Fresnillo unit and $5.76 at the Naica unit.

Ore reserves at the Fresnillo and Naica mines were estimated at 4.55 million tons averaging 5.16-ounces-per-ton silver, 0.010 ounce gold, 5.0 percent lead, 4.8 percent zinc, and 0.32 percent copper.

The Zimpán unit in the State of Hidalgo treated 29,700 tons at its custom flotation mill yielding 0.28 million ounces of silver in addition to lead, zinc, and copper. Average tenor of the ore was 10.8-ounces-per-ton silver, 0.019 ounce gold, 6.75 percent lead, 8.65 percent zinc, and 0.23 percent copper.

Peru.—Peru maintained its rank as the second largest silver-producing country, exceeded only by Mexico. Exports increased about 21 percent to nearly 37.8 million ounces valued at $45.4 million. About 30 percent of the total exports went to the United States.

Cerro de Pasco Corp., which accounted for over one-half of Peru's silver production, reported an output of 21.3 million ounces, a gain of 1.6 million over the 1963 figure. About 47 percent of the company's silver output came from its own mines; the remainder was from purchased ores. Steps to enlarge mine operations at the McCune pit and the Cerro de Pasco mine were begun by installing a new crusher, utilizing additional 40-ton trucks, and preparing to sink a new 1,850-foot production shaft.

Substantial progress leading to increased future production was made by driving the twin-bore 7-mile Graton tunnel at the Casapalca mine. At yearend the tunnel was past the halfway point, and preparatory work was begun for sinking a 2,150-foot shaft to connect present mine workings with the levels to be drained and ventilated by the tunnel.

Cia. Minera Millotingo produced 2.1 million ounces; San Juan de Lucanas produced 1.9 million ounces; and Cia. de Minas Buenaventura, S.A., produced 1.7 million ounces from its Julcani mine and 288,000 from its Huachocolpa lead-zinc operation. Cia. Minera Atacocha, S.A., produced 1.5 million ounces and Cia. des Minas de Huaron produced 1.4 million ounces contained in lead-zinc concentrates. Other companies with a production of over 500,000 ounces in concentrates follow: Cia. Minera Milpo, S.A., Castrovirreyna Metal Mines, Cia. Minera Caylloma, S.A., Cia. Minera Raura, S.A., and Southern Peru Copper Corp. (from copper anodes).

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[9] Pages 14–15 of work cited in footnote 5.

[10] San Francisco Mines of Mexico, Ltd. Report and Accounts for the period ended Dec. 31, 1964.

[11] The Fresnillo Co. Annual Report for the year ended June 30, 1964, pp. 12 and 13.

United Kingdom.—Consumption of silver for industrial uses rose 3 million ounces to 23 million ounces after remaining stable for 3 years.

Imports of silver aggregated 62.4 million ounces, almost triple those of 1963. Nearly 49.2 million ounces, or 80 percent of the total imports, came from the United States. Australia supplied 5.1 million ounces, 2.2 million ounces came from Mexico, and nearly all of the remaining 5.9 million ounces came from 12 other countries. In addition, it was estimated that the equivalent of 1.7 million ounces of silver in coin was received, mostly from Hong Kong.[12]

Silver exports dropped 6.6 million ounces to 21.3 million ounces. Italy and West Germany were the largest buyers, taking 5.6 million ounces and 4.5 million ounces, respectively. About 3.2 million ounces were shipped to France, 3.2 million ounces to Belgium, 1.1 million ounces to Netherlands, and about 3.7 million ounces to other countries.

Of about 2 million ounces recovered from demonetized United Kingdom coins, about 1.5 million ounces was sold on the London market. Approximately 0.5 million ounces was used by the Mint for foreign coinage orders.

TECHNOLOGY

An instrumental technique of determining the existence of mercury halos that may be associated with silver-bearing sulfide deposits was successfully tested in the field.[13] The technique provides a reliable, rapid, and sensitive method for analyzing rocks, soils, and gases for mercury. Detection of mercury is based on the principle of atomic absorption. An analog signal, produced when mercury vapor absorbs ultraviolet light, is converted to digital form and calibrated to mercury concentrations. The lower limit of sensitivity, using a 1-gram sample, is 5 parts per billion.

The treatment of complex silver-cobalt ores occurring with antimony and arsenic was described, and a flow diagram incorporating gravity and flotation principles was presented.[14]

The structural geologic features of the silver deposits at recently operating mines in the Cobalt, Ontario, district were described, and data on ore production and recent developments were discussed.[15]

The basic electrochemistry and characteristics of spacecraft batteries with regard to charging and discharging rates, sensitivity to temperature, energy storage, reliability, and life expectancy were described.[16] The technological material, much of which was supplied by battery manufacturers, on alkaline storage batteries includes data on silver-cadmium and silver-zinc cells and discusses their advantages and limitations.

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[12] Pages 17–20 of work cited in footnote 4.

[13] Vaughn, W. W., and J. H. McCarthy, Jr. An Instrumental Technique for the Determination of Submicrogram Concentrations of Mercury in Soils, Rocks, and Gas. U.S. Geol. Survey, Professional Paper 501–D, 1964 pp. D123–D127.

[14] Deco Trefoil. Gravity and Flotation of Silver-Cobalt. V. 28, No. 4, August-September-October 1964, pp. 21–22.

[15] Cunningham, L. J. A Description of Recent Silver Deposits, Cobalt, Ontario. Canadian Min. J., v. 85, No. 5, May 1964, pp. 49–53.

Silver-bearing copper was reported to have more than 15 percent greater resistance to oxidation at elevated temperatures than silver-free copper. In addition, tests showed that the softening point of silver-bearing copper was 200° F. higher, which made it ideal for resistance to softening in soldering operations.[17]

The manufacture of silver-infiltrated tungsten rocket nozzles for Polaris A–3 missiles employed powder metallurgy principles heretofore considered suitable only for producing small component metal parts. The silver used for infiltration must be in the form of high-purity-metal powder or in a condition that promotes melting and uniformity of processing. Methods used for compacting, sintering, and shaping massive-powder-metal billets and the technology of silver infiltration and machining were described.[18]

An auxiliary silver electrode electrically connected to the positive terminal successfully eliminated the two-step voltage discharge characteristics of the silver-zinc cell by using the AgO capacity on the surface of the positive electrode to charge an auxiliary silver electrode to the Ag_2O state. The increase in energy density resulting from charging the silver electrode to the monovalent state is expected to increase the marketability of silver-zinc and silver-cadmium cells.[19]

Comparison of the oxidation behavior in air of silver-free copper and silver-bearing copper alloys in the temperature range 204° to 371° C. showed an improvement in oxidation resistance in proportion to the silver concentration within the solid solubility limit. The activation energy for oxidation decreased in proportion to solute silver content.[20] The influence of silver concentration on the kinetics of oxidation was attributed to monovalent Ag^+ ion replacement of divalent Cu^{++} ions in the predominant CuO lattice, leading to a reduction in the vacancy concentration required for diffusion.

Several patents were issued for equipment that would increase the sensitivity of photographic silver halide emulsions and other silver-bearing photographic products. A patent[21] also was issued for a method of producing color photographic pictures, composed of at least two component color images, by a silver-dyestuff bleaching process.

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[16] National Aeronautics and Space Administration, Technology Handbook. Space Batteries. NASA SP–5004, 1964, p. 53.

[17] Electronic News. Silver-Bearing Cu Resistance Tested. V. 9, No. 426, Mar. 30, 1964, p. 30.

[18] Backstrom, M. L. Silver-Infiltrated Tungsten Cools Hot Polaris Nozzles. Am. Metal Market, v. 71, No. 120, sec. 2, June 22, 1964, p. 2.

[19] National Aeronautics and Space Administration. Auxiliary Silver Electrode Eliminates Two-Step Voltage Discharge Characteristic of Silver-Zinc Cells. Tech. Brief 64–10114, June 1964, 2 pp.

[20] Hordon, M. J. An Oxidation Resistance Investigation of Silver-Bearing Copper. Copper Range Company, November 1964, 11 pp.

[21] Dreyfuss, Paul (assigned to Ciba Corporation, Summit, N.J.) Method of Producing Color Photographic Pictures U.S. Pat. 3,156,561, Nov. 10, 1964.

Slag

Iron-Blast-Furnace

By William R. Barton[1] and Perry G. Cotter[2]

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PRODUCTION of 86 million tons of pig iron in 1964 yielded an estimated 30 million tons of iron-blast-furnace slag. Of this amount, 90 percent was supplied to slag processors. Output of processed slag increased more than 13 percent in tonnage and 12 percent in value in 1964.

TABLE 1.—Iron-blast-furnace slag processed in the United States by types

(Thousand short tons and thousand dollars)

Year	Air-cooled				Granulated		Expanded		Total	
	Screened		Unscreened		Quantity	Value [1]	Quantity	Value	Quantity	Value
	Quantity	Value	Quantity	Value						
1955–59 (average)	23,640	$37,122	1,505	$1,083	3,805	$1,529	2,924	$8,313	31,874	$48,047
1960	21,908	37,671	1,237	1,049	3,027	1,489	2,626	7,773	28,798	47,982
1961	19,250	33,906	1,493	985	2,663	1,367	2,275	6,806	25,681	43,064
1962	18,496	32,680	312	340	2,385	1,258	2,249	6,615	23,442	40,893
1963	18,290	32,408	689	624	2,461	1,663	2,251	6,703	23,691	41,398
1964	20,969	36,458	621	599	2,840	2,170	2,426	7,273	26,856	46,500

[1] Excludes value of slag used for manufacturing hydraulic cement.

Source: National Slag Association.

DOMESTIC PRODUCTION

Thirty-eight companies, 1 more than in 1963, reported operation of 60 air-cooled, 20 expanded, and 14 granulated slag plants at which 27 million tons of slag was processed.

Slag-encrusted iron reclaimed magnetically by slag processors for remelting amounted to 504,962 tons compared with 403,953 tons in 1963.

The industry's 1,678 plant and yard employees worked a total of 3,828,640 man-hours in 1964 without a disabling injury. Production per man-hour was 7.01 tons compared with 6.66 tons in 1963.

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[1] Commodity specialist, Division of Minerals.

[2] Former commodity specialist, Division of Minerals (now retired).

TABLE 2.—Iron-blast-furnace slag processed in the United States, by States

(Thousand short tons and thousand dollars)

Year and State	Screened air-cooled		All types	
	Quantity	Value	Quantity	Value
1963:				
Alabama	1,911	$3,853	2,321	$4,597
Indiana	2,473	3,169	4,040	5,269
Illinois				
Ohio	3,460	6,554	4,461	8,793
Pennsylvania	4,696	8,809	5,882	10,600
Other States [1]	5,750	10,023	6,987	12,139
Total	18,290	32,408	23,691	41,398
1964:				
Ohio	3,880	7,274	4,973	9,648
Pennsylvania	4,805	9,069	6,242	11,123
Illinois	5,611	8,809	7,361	11,642
Indiana				
Michigan				
Other States [1]	6,673	11,306	8,280	14,087
Total	20,969	36,458	26,856	46,500

[1] Alabama, California, Colorado (1964), Kentucky, Maryland, Michigan (1963), Minnesota, New Jersey (1963), New York, Tennessee (1963), Texas, Utah (1964), and West Virginia.

Source: National Slag Association.

TABLE 3.—Shipments of iron-blast-furnace slag in the United States, by method of transportation

Method of transportation	1963		1964	
	Thousand short tons	Percent of total	Thousand short tons	Percent of total
Rail	6,630	28	5,720	22
Truck	16,259	69	19,920	74
Waterway	576	2	609	2
Total shipments	23,465	99	26,249	98
Interplant handling [1]	226	1	607	2
Total processed	23,691	100	26,856	100

[1] Confined mainly to granulated slag used in manufacturing cement.

Source: National Slag Association.

CONSUMPTION AND USES

Use of screened air-cooled slag for aggregate, railroad ballast, mineral wool, and roofing increased substantially in 1964, but less was used for agriculture and sewage trickling media.

Unscreened air-cooled slag use in highway and airport construction was 152 percent greater in volume than in 1963, and for all uses increased 11 percent.

Cement manufacture accounted for 32 percent of the total 2.8 million tons of granulated slag sold or used by processors in 1964. Slag used for base, subbase, or fill, in road or highway construction, comprised 53 percent of the total, compared with 41 percent in 1963.

Ninety-eight percent of the expanded slag produced was used as aggregate for concrete block manufacture.

TABLE 4.—Air-cooled iron-blast-furnace slag sold or used by processors in the United States, by uses

(Thousand short tons and thousand dollars)

Year and use	Screened		Unscreened	
	Quantity	Value	Quantity	Value
1963:				
Aggregate in—				
Portland cement concrete construction	2,662	$4,969		
Bituminous construction (all types)	3,099	5,889		
Highway and airport construction [1]	7,013	12,565	235	$252
Manufacture of concrete block	438	786		
Railroad ballast	3,093	3,898		
Mineral wool	473	792		
Roofing slag—				
Cover material	348	1,068		
Granules	26	155		
Sewage trickling filter medium	147	287		
Agricultural slag, liming	18	30		
Other uses	973	1,969	454	372
Total	18,290	32,408	689	624
1964:				
Aggregate in—				
Portland cement concrete construction	3,254	5,935		
Bituminous construction (all types)	3,451	6,326		
Highway and airport construction [1]	8,348	14,604	592	579
Manufacture of concrete block	588	1,065		
Railroad ballast	3,211	4,248		
Mineral wool	479	865		
Roofing slag—				
Cover material	361	1,112		
Granules	43	253		
Sewage trickling filter medium	83	146		
Agricultural slag, liming	4	8		
Other uses	1,147	1,896	29	20
Total	20,969	36,458	621	599

[1] Other than in portland cement concrete and bituminous construction.

Source: National Slag Association.

TABLE 5.—Granulated and expanded iron-blast-furnace slag sold or used by processors in the United States, by uses

(Thousand short tons and thousand dollars)

Use	1963				1964			
	Granulated		Expanded		Granulated		Expanded	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
Highway construction (base and subgrade)	745	$1,000			1,176	$1,426		
Fill (road, etc.)	273	268			322	217		
Agricultural slag, liming	61	86			57	98		
Manufacture of hydraulic cement	1,041	NA			905	NA		
Aggregate for concrete block manufacture	160	162	2,206	$6,552	196	283	2,371	$7,083
Aggregate in lightweight concrete								
Other uses	181	147	45	151	184	146	55	190
Total	2,461	[1] 1,663	2,251	6,703	2,840	[1] 2,170	2,426	7,273

NA–Not available.
[1] Excludes manufacture of hydraulic cement, value not available.

Source: National Slag Association.

PRICES

The average value for the total slag produced was $1.73 per ton, a decrease of $0.02 per ton compared with 1963. However, because slag with diverse characteristics is produced for a variety of uses, values ranged from $0.67 per ton for material which received little processing to $5.83 per ton for smaller quantities of slag which required a high degree of screening, sizing, and washing to meet rigid specifications.

Prices for crushed slag (air-cooled, screened) used as aggregate are published regularly for 11 major U.S. cities in Engineering News-Record. At yearend, 1½-inch slag sold for an average $2.37 per ton and ¾-inch slag sold for an average of $2.38 per ton. For the 11 cities where slag prices were quoted, highest prices were in Atlanta and lowest prices in New Orleans and Birmingham, followed closely by Pittsburgh and St. Louis.

TABLE 6.—Average value of iron-blast-furnace slag sold or used by processors in the United States, by uses

(Per short ton)

Use	Air-cooled				Granulated		Expanded	
	Screened		Unscreened					
	1963	1964	1963	1964	1963	1964	1963	1964
Aggregate in—								
Portland cement concrete construction	$1.87	$1.82	-------	-------	-------	-------	-------	-------
Bituminous construction (all types)	1.90	1.83	-------	-------	-------	-------	-------	-------
Highway and airport construction [1]	1.79	1.75	$1.07	$0.98	[2] $1.34	[2] $1.21	-------	-------
Manufacture of concrete block	1.79	1.81	-------	-------	1.01	1.44	$2.97	$2.99
Railroad ballast	1.26	1.32	-------	-------	-------	-------	-------	-------
Mineral wool	1.68	1.81	-------	-------	-------	-------	-------	-------
Roofing slag—								
Cover material	3.07	3.08	-------	-------	-------	-------	-------	-------
Granules	5.95	5.83	-------	-------	-------	-------	-------	-------
Sewage trickling filter medium	1.95	1.76	-------	-------	-------	-------	-------	-------
Agricultural slag, liming	1.64	1.80	-------	-------	1.42	1.70	-------	-------
Fill (road, etc.)	-------	-------	-------	-------	.98	.67	-------	-------
Other uses	2.02	1.65	.82	.71	.81	.79	3.38	3.45

[1] Other than in portland cement and bituminous construction.
[2] Base and subgrade material.

Source: National Slag Association.

TECHNOLOGY

The various methods for producing ball, granulated, foamed, and wool slag to be used in cements, bricks, glass, and soil additives were reviewed. Slags and the additives to make these various types or convert one to the other were discussed.[3]

Subjects discussed at the 20th Annual Meeting of the Pennsylvania Slag Association were antiskid materials, skid resistance tests, slurry seals for pavements, and the use of open hearth slag as aggregate.[4]

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[3] Layton, W. The Nature and Utilization of Iron Blast Furnace Slags. Procs., Australasian Inst. Min. and Met. (Melbourne, Australia). No. 209, March 1964, pp. 93–107.

[4] Pennsylvania Slag Association. Annual Report of the Consulting Engineer. Harrisburg, Pa., Jan. 30, 1964, 12 pp.

The manufacturing process used in making slag cements, optimum compositions of slag glasses, hydration of slag cements, and properties were reported.[5]

Three hundred thousand tons of granulated blast furnace were used by the Cook County, Ill., Highway Department in the construction of an embankment for an elevated section of the Southwest Expressway.[6]

The methods and equipment used to prepare bituminous road mix at the largest blast-furnace slag processing unit in Great Britain were described.[7]

The National Building Research Institute of Pretoria, South Africa, found that supposedly high-magnesia blast-furnace slag could be used for construction. Two mixtures were prepared. One an interground mixture of granulated slag and portland cement clinker, and the other was a finely ground granulated slag that was mixed with portland cement in a concrete mixer on the job. About 350,000 tons of granulated slag was converted to cement by this method and supplied 12 percent of the country's cement requirement.[8]

Studies were made to gain more information on the devitrification and crystallization of molten blast-furnace slag, and the mechanism and hydraulic properties of slag when mixed with portland cement. It was found that when stony or vitreous slags were heated to 800°–900° C., devitrification took place, and the heat evolved during devitrification could be measured by DTA apparatus.[9]

Further evidence was presented to support the theory that the foamibility of blast-furnace slag was governed by the evolution of sulfur-bearing gases, notably hydrogen sulfide.[10]

The Russian Bureau of the Academy of Building and Architecture developed a method for forming housing panels of blast-furnace slag and fly ash. The technology was based upon autoclaving mixtures of foamed slag, waste fly ash from powerplants, unslaked lime, gypsum, silica sand, and portland cement. An aqueous suspension of aluminum powder was introduced in the mix as a foaming agent. Mass construction of large panelled residential blocks using external wall panels of the autoclaved aerated slag-ash concrete was accomplished.[11]

In a method for melting nonamber glass batches so as to reduce the seed level in the glass product, 0.1 to 6.5 percent of blast-furnace slag was added to the usual mix and the batch melted at 2,600° to 2,950° F. The small quantity of slag used did not seriously discolor the glass.[12]

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[5] Nurse, R. W. Slag Cements. Ch. 13 in The Chemistry of Cements. Academic Press Inc. Ltd. (London), v. 2, 1964, pp. 37–67.

[6] American Metal Market. Slag being used for Embankment in Chicago Area. V. 71, No. 126, June 30, 1964, p. 8.

[7] Mine & Quarry Engineering (London). Handling and Coating Slag at Santon. V. 30, No. 3, March 1964, pp. 135–136.

[8] Milner, H. B. Blast-Furnace Cement in South Africa. Nature (London), v. 203, No. 4949, Sept. 25, 1964, p. 1024.

[9] Krueger, J. E., K. H. L. Sehlke, and J. H. P. van Aardt. High-Temperature Studies on Blast-Furnace Slags. Cement & Lime Manufacture (London), v. 37, No. 4, July 1964, pp. 63–70.

[10] Grant, R. M., and W. Layton. A Further Analysis of Possible Mechanisms for the Production of Foamed Blast-Furnace Slags. Australian J. Appl. Science (Sydney, Australia), v. 15, No. 1, March 1964, pp. 10–12.

[11] Rozenfeld, Ben Yaminovich, and N. N. Berezin. Krupnorazmernye Paneli iz Bestsementnogo Autoklavdnogo gazoshlakozolobetona (Large Panels of Autoclaved Aerated Concrete Without Cement Containing Blast-Furnace Slag and Fuel Ash). Betoni Zhelezobeton, No. 2, 1961, pp. 68–83; OTS Transl. 62–32807, Office of Technical Services, U.S. Dept. of Commerce, Washington, D.C.

In an improved method for preparing a stable and readily pumpable concrete in which foamed blast-furnace slag was used, the voids in the aggregate were evacuated under vacuum and then filled with water before the cementitious mix was introduced into the batch.[13]

In the production of a composite expanded shale-blast-furnace slag lightweight aggregate, raw shale and slag were blended to form a mixture consisting essentially of about 42 percent silica, 18 percent alumni, 4 percent trace elements, 6 percent magnesia, and 30 percent lime. The mixture was treated with sodium sulfate or other granular inorganic foaming agent while being passed in a thin stream through a furnace heated to a high enough temperature to fuse and foam the material, ordinarily about 2,450° F.[14]

The results of thermodynamic interprepations of available data on the distribution of sulfur and maganese between liquid pig iron and blast-furnace slags were reported. Special emphasis was given to the role of side reactions and the critical analysis of recent interpretations based on the thermodynamic treatment of slags as ionic solutions.[15]

The correlation between the distribution of sulfur, silicon, and manganese in bath and slag under carbon monoxide partial pressure was investigated.[16]

Tests were applied to mixtures of ground cement clinker and blast-furnace slag of different chemical compositions. The results showed that blast-furnace slag combines with the free lime liberated during the hydration of cement and that only in mixtures of low clinker content is there complete removal of lime, even after prolonged reaction. The maximum lime-fixation capacity of the slag was found to be approximately 5 percent by weight of the mixture liberated from the clinker in a 30 clinker-70 slag mixture.[17]

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[12] Monks, J. R., Jr. (assigned to Owens-Ill. Glass Co., a corporation of Ohio). Glass Melting Method. U.S. Pat. 3,150,991, Sept. 29, 1964.

[13] Albert, R. J. Method of Pumping Concrete Containing Porous Aggregates. U.S. Pat. 3,133,729, May 19, 1964.

[14] Powell, E. R. (assigned to Johns Manville Corp. New York). Process for Making Foamed Ceramic Product. U.S. Pat. 3,133,820, May 19, 1964.

[15] Oelsen, Willy, and Olaf Oelsen. Zur Verteilung von Schwefel und Mangan zwischen Roheisenschmelzen und Hochofenschlacken (On the Partition of Sulfur and Manganese between Pig Iron Melts and Blast Furnace Slags). Arch. für das Eisenhuttenwesen (Dusseldorf, West Germany). V. 5, No. 5, May 1964, pp. 381–388.

[16] Oelsen, Willy. Die Schwefel-und die Manganverteilung zwichen Roheisenschmelzen und Hochofenschlacken un der Kohlenmonoxyddruck im Gas (Sulfur and Manganese Partition between Pig Iron and Blast Furnace Slags and the Carbon Monoxide Pressure). Arch. für das Eisenhuttenwesen (Dusseldorf, West Germany). V. 5, No. 5, May 1964, pp. 389–390.

[17] Fratini, N. The Pozzolanic Properties of Basic Blast Furnace Slag. Silicates Industry, v. 29, Nos. 7 and 8, 1964.

Sodium and Sodium Compounds

By William H. Kerns [1]

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THE TOTAL NATIONAL requirement for sodium carbonate (soda ash) reached a record high in 1964 and a greater portion of the total production (manufactured and natural) was supplied from natural sources than ever before. The Green River area of Wyoming was the center of the increased output and activity for expansion. One major chemical company announced plans for starting a new trona mine and installing a soda ash refinery, and two companies announced expansion of capacity at existing plants. Other new companies to the area were conducting exploration and development with prospects or expectations of starting new operations.

Similarly, total output of sodium sulfate (salt cake) (manufactured and natural) increased substantially to a new high and most of the increase came from natural deposits in California, Texas, and Wyoming. Several major producers of natural-salt cake announced plans for expansion of plant capacity.

DOMESTIC PRODUCTION

Sodium carbonate output, including that of manufactured and natural soda ash, was 6,226,000 tons in 1964, 7 percent greater than the 1963 high record.

Soda ash manufactured from salt by the ammonia-soda process at nine eastern and midwestern plants supplied 80 percent of the total market for soda ash. The plants, two each in Louisiana, Michigan, and Ohio, and one each in New York, Texas, and Virginia, were strategically located in regard to mineral raw-materials supplies of salt and limestone and to chemical markets. The annual production capability of the manufactured soda producers was estimated to be 5,850,000 tons.

The remaining 20 percent of soda ash output was supplied from natural sources of sodium carbonate, lake brines at three operations in California and bedded trona deposits at two operations in Wyoming. In 1964, following a trend established for a decade, production of natural soda ash continued to be the source for a greater portion of the total market and to supply a major part of the yearly increase in total soda required.

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[1] Commodity specialist, Division of Minerals.

TABLE 1.—Manufactured sodium carbonate produced and natural sodium carbonates sold or used by producers in the United States

(Thousand short tons and thousand dollars)

Year	Manufactured soda ash (ammonia-soda process)[1][2]	Natural sodium carbonates[3]	
	Quantity	Quantity	Value
1955-59 (average)	4,758	657	$17,261
1960	4,558	809	20,865
1961	4,516	806	20,444
1962	4,607	978	24,330
1963	4,682	1,119	27,616
1964	p 4,951	1,275	30,451

p Preliminary.
[1] Bureau of the Census.
[2] Includes quantities used to manufacture caustic soda, sodium bicarbonate, and finished light and dense soda ash.
[3] Soda ash and trona (sesquicarbonate).

TABLE 2.—Sodium sulfate produced and sold or used by producers in the United States

(Thousand short tons and thousand dollars)

Year	Production (manufactured[1] and natural)			Sold or used by producers (natural only)	
	Salt cake (crude)	Glauber salt (100 percent $Na_2SO_4 \cdot 10H_2O$)	Anhydrous refined (100 percent Na_2SO_4)	Quantity	Value
1955-59 (average)	717	125	279	340	$6,553
1960	738	72	303	450	8,706
1961	780	64	327	466	9,296
1962	[2] 826	(3)	368	458	9,092
1963	[2] 837	(3)	396	435	8,392
1964	p [2] 944	(3)	p 356	575	10,989

p Preliminary.
[1] Bureau of the Census.
[2] Includes glauber salt converted to 100 percent Na_2SO_4.
[3] Included with salt cake (crude).

In California natural sodium carbonate (and other chemicals) were produced from the brines of Searles Lake by American Potash & Chemical Corp. at its Trona plant and by Stauffer Chemical Co. at its Westend plant. Sodium carbonate was produced from the brines of Owens Lake by Pittsburgh Plate Glass Co. near Bartlett, Calif.

In Wyoming sodium sesquicarbonate (trona) mined from extensive underground deposits near Green River by two companies was processed to and marketed as sodium carbonate. In 1964, FMC Corp., the pioneer in this field in 1947, was again the largest U.S. producer of natural soda ash. By the close of the year FMC had completed an expansion program of its existing facilities that was to increase plant capacity by 85,000 tons to 835,000 tons of soda ash per year. Stauffer Chemical Co., which opened the second mine in the area in 1962, placed new facilities on stream in November that doubled its annual production capacity of soda ash to 400,000 tons.

Allied Chemical Corp., Solvay Process Division, a major U.S. producer of synthetic soda ash, took a step toward natural soda ash production by contracting in November for immediate sinking of a 1,500-foot deep shaft at its planned site for trona mining and processing plant, 12 miles west of Green River. In addition to Allied, other producers of soda ash that reportedly have shown an interest in trona mining near Green River include Texas Gulf Sulphur Co., Diamond Alkali Co., American Potash & Chemical Corp., and Olin Mathieson Chemical Corp. Texas Gulf had acquired trona mining rights on 7,500 acres of government land in the Green River area and conducted test drilling to determine the extent and quality of the trona beds in the area held.

Sodium sulfate production reached a new high of 1.3 million tons and was 5 percent greater than in 1963. About 56 percent of this salt cake output was recovered as byproducts of chemical processes that produced rayon, cellophane, hydrochloric acid, sodium bichromate, boric acid, phenols, and miscellaneous chemicals; 44 percent, compared with 36 percent in 1963, was produced from natural sources. Manufactured sodium sulfate was produced at 40 plants in 16 States, and natural sodium sulfate came from 3 operations in California and 1 operation each in Texas and Wyoming.

In California, American Potash & Chemical Corp. and Stauffer Chemical Co. recovered sodium sulfate from Searles Lake brines at Trona and Westend, respectively; United States Borax & Chemical Corp. produced sodium sulfate as a coproduct in making boric acid from borax at its Wilmington refinery. In Texas, Ozark-Mahoning Co. produced sodium sulfate from subterranean brines at Monahans and Brownfield, and in Wyoming, William E. Pratt recovered sodium sulfate from semidry lakebeds.

In midyear Stauffer Chemical Co. announced a $2 million expansion program at its Westend, Calif., plant to meet anticipated salt cake needs in the growing paper industry of the Pacific Northwest. The expansion program, scheduled for completion in mid-1965, was expected to increase capacity of plant output by 35 percent or 200,000 tons per year.

Late in the year, Ozark-Mahoning Co. announced plans for construction of a plant to come on stream by mid-1965 to produce 72,000 tons per year of high-grade natural salt cake from subterranean brines at Cedar Lake, Tex. The company announced that when the new facility is placed in production, salt cake output at its Brownfield, Tex., plant (115,000 tons per year) would be cut back, and output at its Monahans, Tex., plant (40,000 tons per year) would be kept the same, so that overall production from the three operations would be increased from 155,000 tons to 200,000 tons per year.

Sodium metal production increased 11 percent from 125,566 tons in 1963 to 139,185 tons. Three companies produced sodium and its coproduct, chlorine, by electrolysis of molten salt at five plants: E. I. du Pont de Nemours & Co., Inc., with plants at Niagara Falls, N.Y., and Memphis, Tenn.; Ethyl Corp, with plants at Baton Rouge, La., and Houston, Tex.; and National Distillers & Chemical Corp. at Ashtabula, Ohio.

CONSUMPTION AND USES

Consumption and use patterns of sodium carbonate, sodium sulfate, and sodium metal followed those of the last 5 years. About 44 percent of the total output of sodium carbonate was used in producing glass, 26 percent in chemicals, 9 percent in pulp and paper, 5 percent in soap and detergents, 4 percent each in alumina and for water treatment, and 8 percent for miscellaneous purposes.

An estimated 70 percent of the total sodium sulfate output was consumed in kraft paper manufacture as a reagent in digesting pulpwood. Kraft paper production growth has been brisk enough to offset a declining rate of salt cake consumption per ton of kraft paper produced. This declining rate of consumption, 100 pounds of salt cake now used per ton of paper produced compared with 120 pounds in 1959 and 205 pounds in 1949, resulted from increased efficiency of salt cake recovery from the effluent from pulp paper production. Sodium sulfate also was used in making glass, ceramic glazers, detergents, stock feeds, dyes, textiles, medicines, and various chemicals.

Metallic sodium was used chiefly in making tetraethyl lead (TEL) and tetramethyl (TML), two compounds added in small quantities to motor fuels to increase their antiknock characteristics. Other primary uses of metallic sodium include metal descaling, ore reduction, and manufacture of sodium peroxide, hydride amide, cyanide, borohydride, and other chemicals. The properties of sodium have become recognized in the field of heat transfer. Sodium is used to cool the valves in some internal combustion engines and for removing the heat from atomic piles.

PRICES

Prices quoted for sodium carbonate, sodium sulfate, and metallic sodium by Oil, Paint and Drug Reporter were unchanged from 1963. Prices for these commodities in 1964 were as follows:

Commodity:		*Price*
Sodium carbonate (soda ash 58 percent Na_2O):		
Light, paper bags, carlots, works	per hundred weight	$1.85
Light, bulk, carlots, works	do	1.55
Dense, paper bags, carlots, works	do	1.90
Dense, bulk, carlots, works	do	1.60
Sodium sulfate (100 percent Na_2SO_4):		
Technical, anhydrous, bags, carlots	per ton	[1] 56.00
Technical detergent, rayon grade, bags, carlots, works	do	38.00
Technical detergent, rayon grade, bulk, works	do	34.00
Domestic salt cake, bulk, works	do	28.00
National Formulary (N.F. VII), drums	per pound	.225
Metallic sodium:		
Bricks, lots of 18,000 pounds and more, works	do	.21
Fused, lots of 18,000 pounds and more, works	do	.195
Bulk, tank, works	do	.17

[1] Delivered east of Mississippi River.

FOREIGN TRADE

Imports of sodium carbonate were negligible. Exports of this commodity represented 4 percent of the U.S. total output of manufactured and natural sodium carbonate and were 48 percent greater than in 1963. Of the total exports, 41 percent went to Canada; 32 percent, to Mexico; 11 percent, to Jamaica; 9 percent, to Argentina; 6 percent, to Venezuela; and the remaining 1 percent, to 45 other countries.

Imports of sodium sulfate reached a record high, 81 percent greater than in 1963. More than one-half, or 53 percent, of the imports came from Belgium-Luxembourg; 40 percent, from Canada; and 7 percent, from West Germany. Small quantities totaling less than 1,000 tons came from Mexico and from the Netherlands.

Sodium sulfate exports declined 2 percent, compared with 1963, and accounted for about 3 percent of the sodium sulfate produced (manufactured and natural) and sold or used in the United States in 1964. Forty-eight percent of the total exports went to Mexico and 46 percent to Canada; the remaining 6 percent was exported to 26 other countries.

TABLE 3.—U.S. imports for consumption of sodium sulfate

(Thousand short tons and thousand dollars)

Year	Crude (salt cake)		Anhydrous		Total [1]	
	Quantity	Value	Quantity	Value	Quantity	Value
1955–59 (average)	101	$2,058	3	$93	104	$2,152
1960	164	3,411	3	62	167	3,473
1961	193	4,089	3	64	196	4,153
1962	181	3,646	7	122	188	3,768
1963	r 159	r 3,084	1	27	r 160	r 3,111
1964	288	5,035	2	29	290	5,064

r Revised.

[1] Includes glauber salt, as follows: 1958, 12 tons ($830); 1959, 227 tons ($4,839); 1960, 7 tons ($479); 1961–62 none; 1963, 3 tons ($285); 1964, 4 tons ($355).

Source: Bureau of the Census.

Table 4.—U.S. exports of sodium carbonate and sodium sulfate

(Thousand short tons and thousand dollars)

Year	Sodium carbonate		Sodium sulfate	
	Quantity	Value	Quantity	Value
1955–59 (average)	165	$5,871	24	$871
1960	155	5,143	31	940
1961	132	4,045	32	992
1962	152	4,693	51	1,486
1963	184	5,722	45	1,379
1964	273	8,368	44	1,320

Source: Bureau of the Census.

Tariff rates of sodium carbonate and sodium sulfate were as follows:

	Tariff rate per short ton August 31, 1964
Sodium carbonate:	
Calcined (soda ash)	$5.00
Hydrated and sesquicarbonate	5.00
Sodium sulfate:	
Crude (salt cake)	Free
Anhydrous	.50
Crystallized (Glaubers salt)	1.00

WORLD REVIEW

Brazil.—Carbocloro Indústrias Quimicas, Ltda., (Diamond Alkali Co. with Brazilian partners) $10-million caustic-chlorine complex near Santos at Cubatão, São Paulo, went on stream early in the year. Initial monthly output was to be 110 tons of caustic soda, 110 tons of chlorine, and 55 tons of hydrochloric acid. According to the company, with a minimum additional investment it could become the largest producer of caustic and chlorine in the Southern Hemisphere.[2]

Japan.—In April the Ministry of International Trade and Industry authorized importation of 10,000 tons of Kenya produced soda ash into Japan to correct a temporary imbalance between supply and demand. In October fearing that their own production position would be impared, four Japanese makers of soda ash appealed to the Ministry to delay plans for liberalization of trade of this commodity pending a further investigation into the position of the domestic soda ash industry.[3]

Peru.—In April Industrias Qúimicas del Perú, a new company formed by Morton Salt Co. and Rayon Peruana, S.A., officially dedicated its $3.5 million caustic soda plant near Ventanilla, Lima's satellite city. Initial daily output was planned for 15 tons of caustic soda and 25 tons of decalcium phosphate.[4]

Philippines.—In July, the caustic soda plant of International Chemical Industries, the first major operation of its kind in the Philippines, was formally dedicated by President Macapagal. The plant, 19 miles from Manila, has an annual capacity of 13,200 tons of caustic soda and 11,900 tons of chlorine. Plans are to expand the capacity 60 percent in 1965 with installation of additional electrolytic cells.[5]

Rumania.—The largest mercury cathode electrolytic alkali plant in Rumania was completed at the Borzesti Chemical Combine in August. The new annual capacity of 50,000 tons of rayon-grade caustic, 45,000 tons of chlorine, and 14 million cubic feet of hydrogen is double the old capacity. The hydrogen was to be used mainly for hydrogen chloride synthesis.[6]

South Africa, Republic of.—Most of South African soda ash needs were in the past supplied by an Imperial Chemical Industries, Ltd. (ICI) plant at Magadi, Kenya. But late in 1963 Kenya cut off supplies for political reasons, and since then ICI supplied soda ash directly from the United Kingdom. However in August of 1964 the South West Africa Co., Ltd., announced that it had investigated the possibility of producing soda ash from deposits of natural sodium salts (a mixture of carbonate, bicarbonate, and sulfate) in the Otjivalunda Pans, west of the Etosha Pan, in South-West Africa and that it would embark immediately on a program to develop the pans to meet requirements of the Republic of South Africa for soda ash for many years.[7]

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[2] Chemical Week. V. 94, No. 17, Apr. 25, 1964, pp. 61–62.

[3] Mining Journal (London). Japanese Soda Ash Difficulties. V. 263, No. 6738, Oct. 9, 1964, p. 267.

[4] Bureau of Mines. Mineral Trade Notes. V. 59, No. 4, October 1964, p. 45.

[5] Bureau of Mines. Mineral Trade Notes. V. 59, No. 4, October 1964, p. 46.

[6] Chemical Trade Journal and Chemical Engineer (London). Latest Electrolytic Alkali Plant. V. 155, No. 4027, Aug. 17, 1964, p. 201.

[7] Chemical Trade Journal and Chemical Engineer (London). Soda Ash Decision. V. 155, No. 4026, Aug. 7, 1964, p. 170.

U.S.S.R.—Production of soda ash in the Soviet Union in 1963 totaled 2.5 million tons. From 1958 to 1963 output of soda ash rose by 47.7 percent. This country now occupies second place after the United States for this chemical. In 1962 the Soviet Union imported 190,000 tons of soda ash, more than three times the quantity exported.[8]

United Kingdom.—In a new British standard for sodium carbonate (B.S. 3674), specifications were given for two types of sodium carbonate, hydrated product used as a general household and industrial detergent and anhydrous sodium carbonate used in a wide range of industrial applications, particularly in glassmaking and in the heavy chemical industry. The standard gives limits for total alkali content, matter insoluble in water, and sulfate, chloride, and iron contents. Appropriate methods of testing the sodium carbonate also are given, including one for determining the pouring density.[9]

TECHNOLOGY

Two booklets[10] were published by FMC Corp. describing the processes used to mine and refine trona to produce soda ash at its Westvaco facilities near Green River, Wyo. Two mining techniques—called conventional and continuous—are employed to extract the trona ore. Conventional mining, which has been used since 1947 when operations began, is a modification of the room-and-pillar mining method. Within the past few years FMC has been instrumental in developing a continuous-type mining machine, which bores out the trona directly—eliminating cutting, drilling, and blasting needs of the conventional mining method. Methods for pillar extraction also have been perfected to remove a higher percentage of the available ore.

In the treatment plant, the trona ore is crushed and ground, and hot water is added to dissolve the trona. Most of the impurities in the ore are insoluble in hot water. The undissolved particles or impurities are removed in settling ponds and filters, and the clear hot solution containing trona is cooled under vacuum, causing the trona to recrystallize in needlelike form. These crystals are removed and the excess water and carbon dioxide are driven off in rotary calciners to form soda ash.

The soda ash is shipped in bulk hopper cars or in 100-pound bags. In midyear, it was announced[11] that the company had purchased 100 jumbo-sized railway hopper cars, each with a capacity of 4,600 cubic feet of soda ash, and had placed an order for additional cars to increase its present fleet.

High-purity sodium sesquicarbonate for use as a high-whiteness blending agent in hard-surface household, industrial, and dairy cleaners is a new product at the FMC soda ash plant at Westvaco. This material, the first product other than soda ash marketed from this operation, is produced by crystallizing, centrifuging, and drying a specially prepared solution of trona ore, which is actually sodium sesquicarbonate in a less pure form.[12]

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[8] European Chemical News (London). Soviet Soda Ash Output Increasing Steadily. V. 5, No. 112, Mar. 6, 1964, p. 4.

[9] Chemical Age (London). New British Standard for Sodium Carbonate. V. 91, No. 2322, Jan. 11, 1964, p. 94.

[10] FMC Corp., Inorganic Chemicals Division. What's Different About FMC Soda Ash? 1964, 35 pp.

———. Intermountain Chemical Co. In the Green River Basin of Wyoming, 1964, 33 pp.

[11] Oil, Paint and Drug Reporter. FMC Buys Hoppers. V. 186, No. 25, June 22, 1964, p. 27.

Coproducts chlorine and caustic soda or sodium hydroxide (NaOH) are produced from salt by electrolysis. About one-half of world chlorine production of 10 million tons per year is used in chlorination of hydrocarbons from which byproduct hydrogen chloride or hydrochloric acid (HCl) is recovered. The demands for NaOH and HCl have not increased proportionately in recent years to the demand for chlorine. Farbwerke Hoechst A. G. announced[13] a new commercialized process that is ideally suited to easing this market picture. In this process, high-purity chlorine and hydrogen are produced by electrolytic decomposition of byproduct HCl obtained from chlorination of hydrocarbon, and no NaOH is produced. The company built and since June has satisfactorily operated a plant in Frankfurt, West Germany, having a chlorine capacity of 110 tons per day.

Using a new pyrometallurgical process and magnetic separation, a process to recover caustic soda and iron from material remaining after alumina is produced from bauxite reportedly was developed by Hungarian metallurgists. At the close of the year, a large pilot plant to test this new process was under construction at the Almasfuezitoe aluminum works in western Hungary.

A British patent (No. 936,431) was issued for a process for concentrating sodium sulfate solution by introducing it into the top of a chamber in an unsupported liquid-film. This film is atomized in a downward direction by flowing hot air against the liquid-film. The film of liquid is produced by pumping the solution through a narrow tube on to a curved plate of fishtail shape. The hot air nozzle may also be of fishtail shape. The airblast discharges directly into the liquid-film as it leaves the plate.

A method for producing high-purity metallic sodium was patented.[14] A direct electric current is passed through a bicomponent-fused bath mixture consisting of 15 to 40 percent sodium chloride and 85 to 60 percent strontium chloride, respectively, and recovering the metallic sodium displaced from the fused-bath mixture that contains a maximum of 2.5 percent of other chloride salts as impurities.

An inexpensive technique that laboratory studies indicated would significantly reduce water seepage in irrigation canals was devised and tested by the Bureau of Mines through research sponsored by the Bureau of Reclamation and the Missouri River Basin Field Committee. Laboratory studies simulating optimum field conditions determined that easily applied sodium carbonate solutions made test beds of canal lining material virtually impermeable for long periods.[15]

Laboratory phase rule studies were made in search of an economical process for separating the saline constituents of Great Salt Lake.[16]

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[12] Chemical Engineering. Sodium Sesquicarbonate from Trona. V. 71, No. 8, Apr. 13, 1964, p. 88.

[13] Grosselfinger, F. B. New Chlorine Source: Byproduct Hydrochloric. Chem. Eng., v. 71, No. 19, Sept. 14, 1964, pp. 172–174.

[14] Thomas, Wilford H. (assigned to Ethyl Corp., New York). Production of Sodium. U.S. Pat. 3,119,756, Jan. 28, 1964.

[15] Agey, W. W., and B. F. Andrew. Reduction of Seepage Losses from Canals by Chemical Sealants (in 2 parts). 1. Laboratory Research on Sodium Carbonate and Other Compounds. BuMines Repts. of Inv. 6584, 1965, 33 pp.

[16] Glassett, J. M., and B. J. Anderson. The Recovery of Salts from the Waters of Great Salt Lake. Univ. of Utah, Bulletin 128, v. 55, No. 21, May 1964, 80 pp.

Stone

By William R. Barton[1] and Perry G. Cotter[2]

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COMBINED production of dimension and crushed and broken stone exceeded $1 billion in value for the third consecutive year. The 1964 total of $1.13 million established a new record high. Crushed and broken stone represented 91 percent of this total value.

TABLE 1.—Salient stone statistics [1]

(Thousand short tons and thousand dollars)

	1955-59 (average)	1960	1961	1962	1963	1964
Sold or used by producers:						
Dimension stone	2, 547	2, 257	2, 315	2, 729	2, 616	2, 545
Value	$83, 512	$86, 009	$88, 093	$90, 687	$96, 318	$96, 970
Crushed stone	524, 676	614, 527	609, 623	654, 225	685, 750	722, 724
Value	$729, 951	$866, 546	$859, 266	$935, 010	$971, 790	$1, 037, 365
Total stone	527, 223	616, 784	611, 938	656, 954	688, 366	725, 269
Value	$813, 463	$952, 555	$947, 359	$1, 025, 697	$1, 068, 108	$1, 134, 335
Imports for consumption (value) [2]	$8, 351	$11, 344	$12, 268	$17, 204	$18, 978	$22, 916
Exports (value)	$6, 231	$6, 166	$6, 648	$6, 009	$6, 102	$6, 796

[1] Includes slate. 1955-56 includes territories of the United States, possessions, and other areas administered by the United States.
[2] Includes whiting.

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[1] Commodity specialist, Division of Minerals.
[2] Former commodity specialist, Division of Minerals (now retired).

TABLE 2.—Stone sold or used by producers in the Unitd States, by States

(Thousand short tons and thousand dollars)

State	1963		1964	
	Quantity	Value	Quantity	Value
Alabama	[1] 13,684	[1] $22,206	[1] 15,852	[1] $24,976
Alaska	W	W	W	W
Arizona	3,257	5,069	3,759	6,283
Arkansas	18,913	22,727	20,241	26,172
California	37,977	58,253	45,805	63,566
Colorado	2,510	5,693	3,217	6,805
Connecticut	5,318	9,612	5,864	10,764
Delaware	W	W	W	W
Florida	31,900	38,173	33,157	38,362
Georgia	19,582	46,044	22,730	46,532
Hawaii	3,844	6,480	5,282	8,765
Idaho	1,168	2,217	1,144	2,773
Illinois	40,293	52,217	42,987	56,553
Indiana	19,667	35,616	22,318	39,978
Iowa	20,904	27,788	23,935	33,038
Kansas	13,558	18,483	14,138	18,912
Kentucky	24,689	34,571	[1] 21,868	[1] 29,594
Louisiana	[1] 5,408	[1] 7,961	[1] 5,459	[1] 7,228
Maine	947	3,581	1,414	4,506
Maryland	13,012	26,407	13,348	26,715
Massachusetts	5,570	14,396	6,519	16,663
Michigan	30,316	32,065	34,650	37,002
Minnesota	3,898	11,027	3,588	12,297
Mississippi	1,267	1,267	1,553	1,557
Missouri	30,885	46,130	31,487	47,984
Montana	6,109	7,081	7,345	8,477
Nebraska	3,700	6,192	3,779	6,417
Nevada	639	1,101	788	1,396
New Hampshire	137	1,566	202	2,138
New Jersey	11,229	25,654	12,326	28,461
New Mexico	2,509	4,236	2,760	4,244
New York	26,611	44,549	29,141	46,669
North Carolina	15,701	25,683	[1] 17,943	[1] 30,378
North Dakota	132	132	31	56
Ohio	37,537	62,787	37,715	61,814
Oklahoma	13,817	16,160	13,987	15,087
Oregon	19,692	24,197	16,120	19,296
Pennsylvania	49,536	83,450	52,829	91,075
Rhode Island	442	968	450	935
South Carolina	7,262	10,926	[1] 6,109	[1] 9,176
South Dakota	2,794	7,339	2,118	6,245
Tennessee	26,825	38,113	[1] 26,497	[1] 38,239
Texas	43,142	54,007	40,240	52,070
Utah	2,346	4,040	3,105	6,930
Vermont	2,159	19,193	2,070	20,652
Virginia	27,653	45,529	30,407	52,153
Washington	12,934	16,346	10,276	14,871
West Virginia	[1] 9,452	[1] 14,489	[1] 7,481	[1] 13,105
Wisconsin	13,583	18,744	13,901	20,232
Wyoming	1,940	2,991	2,154	3,671
Undistributed	1,918	4,652	5,180	13,523
Total	688,366	1,068,108	725,269	1,134,335
American Samoa	944	2,351	157	234
Canton Island	2	6	0	0
Guam	307	439	469	868
Panama Canal Zone	162	281	153	349
Puerto Rico	5,334	8,237	5,504	8,586
Virgin Islands	66	329	69	342
Wake Island	9	51	2	5

W Withheld to avoid disclosing individual company confidential data; included with "Undistributed."

[1] To avoid disclosing individual company confidential data, certain State totals are incomplete, the portion not included being combined with "Undistributed." The class of stone omitted from such State totals is noted in the State tables in the Statistical Summary chapter of this volume.

TABLE 3.—Stone sold or used by producers in the United States, by kinds

(Thousand short tons and thousand dollars)

Year	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
	Granite		Basalt and related rocks (traprock)		Marble		Limestone and dolomite		Shell	
1955–59 (average)	33,377	$69,894	42,817	$68,396	1,353	$24,359	390,190	$534,914	18,635	$29,049
1960	42,748	89,654	57,884	87,699	1,644	31,060	451,253	623,437	18,934	33,706
1961	44,058	93,870	62,776	95,576	1,592	30,960	438,253	608,139	18,004	30,375
1962	50,058	102,898	69,768	108,264	1,769	33,117	461,849	649,647	20,054	31,241
1963	48,793	103,633	72,958	111,538	1,902	34,567	489,243	680,060	19,019	29,420
1964	56,239	114,569	66,090	108,929	2,093	36,693	510,804	713,342	19,493	30,157
	Calcareous marl		Sandstone		Slate		Other stone [1]		Total	
1954–59 (average)	[2]1,921	[2]$1,797	17,075	$46,852	666	$11,671	21,189	$26,531	527,223	$813,463
1960	1,283	1,353	21,013	48,771	532	9,233	21,493	27,642	616,784	952,555
1961	1,099	987	23,386	49,114	496	9,334	22,274	29,004	611,938	947,359
1962	1,182	1,011	26,077	51,119	544	10,100	25,653	38,300	656,954	1,025,697
1963	1,164	989	28,978	58,015	902	11,365	25,407	38,521	688,366	1,068,108
1964	1,043	899	28,169	62,087	1,303	13,695	40,035	53,964	725,269	1,134,335

[1] Includes mica schist, conglomerates, argillite, various light-colored volcanic rocks, serpentine not used as marble, soapstone sold as dimension stone, etc.

[2] Average for 1957–59 only.

LEGISLATION AND GOVERNMENT PROGRAMS

Bills (S. 2765, H.R. 11615) were presented to the 88th Congress to clarify the term "common varieties" as used in certain U.S. mining laws (61 Stat. 681—7/31/47 and 69 Stat. 368—7/23/55). The bills were not acted on before the session terminated. The Internal Revenue Service issued Revenue Ruling 64–49 defining ordinary treatment processes considered as mining in the case of chemical grade limestone, crushed rock for road ballast, agricultural limestone, granite, and other crushed or broken stone. It classified as mining all separating, screening, and size reduction processes except "fine pulverization." It also defined "fine pulverization."

DIMENSION STONE

The slight decrease in volume of shipments of dimension stone may have been due to the continued tendency to use thin veneers and smaller monuments.

As the inherent disadvantages of some competing materials such as glass, plastic, and metals became more widely recognized, many newer stone products, such as stone-faced precast concrete panels, were receiving increasingly favorable attention. The popularity of travertine to obtain unusual exterior textures continued, but exposed aggregate panels also were increasing in vogue for the same reason and this type of finish competed with stone cladding as well as concrete and metal-glass exteriors. Darker colored stones, such as black granite, were of renewed interest to architects to effect contrast with the light-colored buildings dominant in American cities. Outstanding examples were the new CBS building in New York City designed in black granite by the late Eero Saarinen and the United States Gypsum Building in Chicago in dark Virginia slate by Perkins and Wills. Thin, translucent panels of marble or onyx marble were also used increasingly in place of glass windows in prestige buildings such as banks and college libraries.

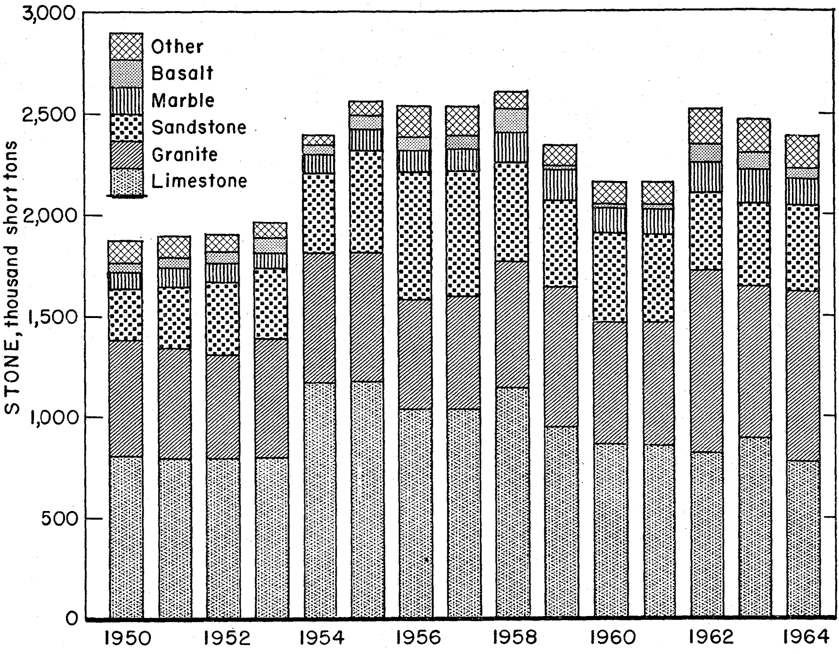

FIGURE 1.—Sales of dimension stone, except slate, in the United States, by kinds.

Granite.—The value of shipments of dimension granite increased almost 4 percent over that of 1963. Shipments of dressed architectural granite decreased 11 percent in tonnage and 5 percent in value. Monumental granite also decreased in tonnage and value. A popular discussion of economically useful igneous and metamorphic rocks including granite was published.[3]

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[3] Tomkeieff, S. I. The Economic Geology of Quarried Materials—Igneous and Metamorphic Rocks. Quarry Managers. J. (London), v. 48, No. 3, March 1964, pp. 85–94.

TABLE 4.—Dimension stone sold or used by producers in the United States, by uses

Use	1963			1964		
	Thousand short tons	Thousand cubic feet	Value (thousands)	Thousand short tons	Thousand cubic feet	Value (thousands)
Building:						
Rough:						
Construction	271	------------	$2,103	385	------------	$2,800
Architectural[1]	311	4,170	6,677	367	4,868	7,669
Dressed:						
Sawed[1]	524	6,802	20,136	521	6,807	21,462
Cut	226	2,943	26,764	[2] 202	[2] 2,540	[2] 26,420
Rubble	620	------------	2,687	391	------------	2,041
Roofing (slate)	32	------------	1,965	33	------------	2,228
Millstock (slate)	30	------------	3,825	28	------------	3,951
Monumental (rough and dressed)[3]	277	3,341	24,099	241	2,940	20,464
Paving blocks	4	------------	86	6	------------	163
Curbing	153	1,867	4,026	168	2,038	4,682
Flagging[4]	168	2,029	3,950	203	2,455	5,090
Total	2,616	------------	96,318	2,545	------------	96,970

[1] Includes stone for refractory use to avoid disclosing individual company confidential data.
[2] Includes a small quantity of stone for precision surface plates and monumental work.
[3] Includes stone for precision surface plates.
[4] Includes a small quantity of slate for miscellaneous uses.

TABLE 5.—Granite (dimension stone) sold or used by producers in the United States, by uses

Use	1963			1964		
	Thousand short tons	Thousand cubic feet	Value (thousands)	Thousand short tons	Thousand cubic feet	Value (thousands)
Building:						
Rough:						
Construction	33	------------	$337	250	------------	$1,195
Architectural	28	340	1,061	43	515	1,599
Dressed:						
Construction	21	253	1,460	16	190	1,240
Architectural	57	683	8,415	51	622	7,984
Rubble	225	------------	768	89	------------	398
Monumental:[1]						
Rough	175	2,131	8,692	174	2,128	8,852
Dressed	59	716	8,037	49	596	7,777
Paving blocks	4	------------	86	6	------------	163
Curbing and flagging	151	1,837	3,940	165	1,994	4,544
Total	753	------------	32,796	843	------------	33,752

[1] Includes stone for precision plates.

TABLE 6.—Granite (dimension stone) sold or used by producers in the United States in 1964, by States

State	Active plants	Short tons	Value	State	Active plants	Short tons	Value
California	9	13,007	$1,304,264	North Carolina	10	43,592	$2,773,675
Colorado	4	655	40,150	Oklahoma	6	2,961	219,270
Connecticut	5	2,908	78,075	South Carolina	5	7,479	204,950
Georgia	30	167,791	3,683,385	South Dakota	7	17,803	2,807,851
Maine	8	18,974	1,779,151	Texas	5	226,596	1,056,308
Maryland	1	556	20,016	Utah	1	800	160,000
Massachusetts	13	130,065	4,207,496	Wisconsin	13	10,773	1,994,606
Minnesota	19	37,511	5,132,863	Other States [1]	19	136,225	7,696,316
Missouri	1	3,226	292,228				
New Mexico	1	120	4,000	Total	161	843,446	33,752,034
New York	4	22,404	297,430	Puerto Rico	--------	7,400	23,700

[1] Includes New Hampshire 2 plants; Pennsylvania 4; Rhode Island 2; Vermont 10; and Virginia 1.

Basalt and Related Rocks (Traprock).—Total shipments of dimension basaltic-type rocks were 45,375 tons valued at $632,887.

Washington produced the greatest tonnage, although Pennsylvania's production, second in volume, led in value. Oregon, California, and Michigan also reported production.

Marble.—The reported value of dimension marble was 8 percent less than in 1963. The average value for monumental marble (rough and finished) was $17.75 per cubic foot. A quarry for black marble was reopened 10 miles south of Batesville, Ark., after a 25-year dormancy.

Limestone.—Shipments of dimension limestone decreased 13 percent in tonnage and increased 4 percent in value. The Bedford-Bloomington, Ind., area continued to lead in production of this type of stone. Veneers and stone-faced precast panels continued to increase their share of available markets, at the expense of massive architectural blocks. The occurrence, properties, and uses of limestones were described.[4]

TABLE 7.—Marble (dimension stone) sold or used by producers in the United States,[1] by uses

Use	1963			1964		
	Thousand short tons	Thousand cubic feet	Value (thousands)	Thousand short tons	Thousand cubic feet	Value (thousands)
Building: [2]						
Rough: Architectural	28	343	$1,134	28	325	$1,031
Dressed:						
Sawed	34	415	3,100	36	424	3,888
Cut	46	550	9,474	48	568	10,491
Monumental (rough and finished)	42	489	7,294	18	216	3,835
Total	150	------------	21,002	130	------------	19,245

[1] Produced by the following States in 1964 in order of value and with number of plants: Vermont 8; Georgia 1; Alabama 2; Tennessee 12; Missouri 4; Arkansas 2; North Carolina 1; New Mexico 1; Montana 1; Colorado 1; Washington 3; Arizona 2; California 1; and Maryland 1.

[2] Includes: 1963— 843,000 cu. ft., $7,351,000 for exterior use, and 465,000 cu. ft., $6,357,000 for interior use; 1964— 882,000 cu. ft., $8,697,000 for exterior use, and 435,000 cu. ft., $6,713,000 for interior use.

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[4] Tomkeieff, S. I. The Economic Geology of Quarried Materials—Limestones. Quarry Managers J. (London), v. 48, No. 5, May 1964, pp. 169–178.

Sandstone.—Shipments of dimension sandstone increased 5 percent in quantity and decreased 7 percent in value compared with those of 1963. Two hundred and seven plants reported shipments in 1964, compared with 215 plants a year earlier. The economic evaluation of sandstone deposits and their utilization were discussed.[5]

Slate.—Shipments of slate increased 7 percent in quantity and almost 13 percent in value compared with those of 1963. On a tonnage basis, flagstones were the leading dimension slate product, but the most important products in order of value were millstock and roofing slate. Use of alternate materials resulted in continuation of the decline in blackboard slate.

Miscellaneous Stone.—Shipments of miscellaneous stone decreased 5 percent in tonnage and increased 10 percent in value over those of 1963. This category accounted for less than 6 percent of the volume of dimension stone shipments and consisted of stones not classified under the more popular categories. Examples of such stones included light-colored volcanics, tuffs, greenstones, gneisses, schists, and argillite.

TABLE 8.—Limestone (dimension stone) sold or used by producers in the United States, by uses

Use	1963			1964		
	Thousand short tons	Thousand cubic feet	Value (thousands)	Thousand short tons	Thousand cubic feet	Value (thousands)
Building:						
Rough:						
Construction	52	----------	$289	23	----------	$266
Architectural	196	2,710	3,091	239	3,284	3,928
Dressed:						
Sawed [1]	261	3,497	7,729	273	3,669	8,070
Cut	86	1,177	5,769	65	860	5,826
Rubble	282	----------	1,104	155	----------	694
Curbing and flagging	18	230	152	24	312	160
Total	895	----------	18,134	779	----------	18,944

[1] Includes house stone veneer.

TABLE 9.—Limestone (dimension stone) sold or used by producers in the United States in 1964, by States

State	Active plants	Short tons	Value	State	Active plants	Short tons	Value
California	6	3,200	$27,869	Ohio	4	4,185	$14,029
Georgia	1	876	6,208	Oklahoma	5	2,937	31,588
Illinois	3	5,135	141,488	Pennsylvania	1	60	420
Indiana	22	534,296	12,232,884	Texas	5	16,043	457,084
Iowa	2	8,753	169,272	Wisconsin	33	98,389	1,872,805
Kansas	10	14,313	502,499	Other States [1]	5	22,059	962,252
Michigan	3	5,383	68,711				
Minnesota	6	29,795	2,323,396	Total	116	779,236	18,943,710
Missouri	6	21,380	73,923	Puerto Rico	--------	74,850	190,650
Nebraska	4	12,432	59,282				

[1] Includes Alabama 2 plants; New York 1; Rhode Island 1; and Utah 1.

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[5] Tomkeieff, S. I. The Economic Geology of Quarried Materials—Sandstones. Quarry Managers J. (London), v. 48, No. 10, October 1964, pp. 397–402.

TABLE 10.—Limestone sold by producers in the Indiana oolitic limestone district, by classes

Year	Construction					
	Rough blocks		Sawed and semifinished [1]		Cut	
	Thousand cubic feet	Value (thousands)	Thousand cubic feet	Value (thousands)	Thousand cubic feet	Value (thousands)
1955-59 (average)	2,965	$3,176	3,377	$6,118	927	$5,451
1960	2,817	2,934	2,846	5,340	528	3,005
1961	2,820	3,159	2,498	4,675	497	2,784
1962	2,467	2,695	2,427	4,674	560	3,251
1963	2,183	2,533	2,518	5,217	530	2,258
1964	3,035	3,535	[2] 2,752	[2] 5,770	400	2,624

Year	Construction—Continued			Other uses		Total	
	Total						
	Thousand cubic feet	Thousand short tons	Value (thousands)	Thousand short tons	Value (thousands)	Thousand short tons	Value (thousands)
1955-59 (average)	7,269	527	$14,745	170	$459	697	$15,204
1960	6,191	449	11,279	139	413	588	11,692
1961	5,815	422	10,618	161	515	583	11,133
1962	5,454	395	10,620	191	659	586	11,279
1963	5,231	379	10,008	197	640	576	10,648
1964	6,187	449	11,929	71	225	520	12,154

[1] Includes house stone veneer.
[2] Includes small quantity produced outside the district.

TABLE 11.—Sandstone (dimension stone) sold or used by producers in the United States, by uses

Use	1963			1964		
	Thousand short tons	Thousand cubic feet	Value (thousands)	Thousand short tons	Thousand cubic feet	Value (thousands)
Building:						
Rough:						
Construction	99	------------	$1,308	95	------------	$1,205
Architectural [1]	59	774	1,370	57	744	1,111
Dressed:						
Sawed [1]	113	1,519	4,167	122	1,654	4,263
Cut	36	521	2,760	37	471	1,677
Rubble	49	------------	365	46	------------	325
Curbing	2	28	82	3	42	133
Flagging	54	669	1,391	71	872	1,901
Total	412	------------	11,443	431	------------	10,615

[1] Includes stone for refractory use to avoid disclosing individual company confidential data.

TABLE 12.—Sandstone (dimension stone) sold or used by producers in the United States in 1964, by States

State	Active plants	Short tons	Value	State	Active plants	Short tons	Value
Alabama	1	182	$2,029	Ohio	17	124,081	$4,707,623
Arizona	16	14,050	211,335	Pennsylvania	41	94,535	1,431,871
Arkansas	5	13,529	200.791	Tennessee	16	39,462	1,032,391
California	7	1,831	22,777	Texas	1	980	4,900
Colorado	29	24,516	418,884	Utah	6	1,645	58,457
Georgia	1	510	12,866	Virginia	4	1,551	20,029
Kansas	1	447	8,887	Wisconsin	11	5,697	84,802
Massachusetts	1	1,590	159,000	Wyoming	5	480	6,740
Michigan	5	8,306	62,030	Other States [1]	25	48,677	865,673
Missouri	2	2,208	29,239				
New York	13	46,301	1,274,864	Total	207	430,578	10,615,188

[1] Includes Connecticut 2 plants; Indiana 6; Kentucky 2; Maryland 3; Nevada 3; New Mexico 3; Washington 4; and West Virginia 2.

TABLE 13.—Slate (dimension stone) sold or used by producers in the United States,[1] by uses

Use	1963			1964		
	Quantity		Value (thousands)	Quantity		Value (thousands)
	Thousand short tons	Unit of measurement		Thousand short tons	Unit of measurement	
Roofing slate	32	*Thousand squares* 81	$1,965	33	*Thousand squares* 88	$2,228
Millstock:		*Thousand sq. ft.*			*Thousand sq. ft.*	
Electrical, structural, and sanitary slate	26	2,838	2,700	24	2,897	2,822
Blackboards and bulletin boards [2]	2	985	904	2	941	840
Billiard tabletops	2	215	221	2	274	289
Total	30	4,038	3,825	28	4,112	3,951
Flagstones [3]	63	12,344	1,635	60	11,132	1,481
Miscellaneous uses [4]	28		630	43		1,426
Grand total	153		8,055	164		9,086

[1] Produced by the following States in 1963 in order of value of output and with number of plants: Pennsylvania 10; Vermont 20; Virginia 2; New York 11; Maine 1; North Carolina 2; and California 1.

[2] Includes a small quantity of school slates.

[3] Includes slate used for walkways and stepping stones.

[4] Includes slate for aquarium bottoms, buildings, fireplaces, flooring, headstones, shims, and unspecified uses.

TABLE 14.—Miscellaneous varieties of dimension stone sold or used by producers in the United States,[1] by uses

Use	1963			1964		
	Thousand short tons	Thousand cubic feet	Value (thousands)	Thousand short tons	Thousand cubic feet	Value (thousands)
Building:						
Sawed [2]	95	1,118	$3,680	74	870	$4,001
Rubble	60		446	74		572
Flagging	5	59	142	5	59	122
Total	160		4,268	153		4,695

[1] Produced by the following States in 1964 in order of value of output and with number of plants: Virginia 2 plants; California 26; Maryland 1; Pennsylvania 5; Hawaii 4; Connecticut 2; New Mexico 2; Colorado 2; Washington 1; Montana 1; and Arizona 1.

[2] Includes rough and cut stone and stone for refractory use to avoid disclosing individual company confidential data.

FOREIGN TRADE

Imports of decorative and speciality marbles (including travertine and onyx) in 1964 totaled $12,199,641 and came principally from Italy, although substantial amounts were also reported from Mexico, Portugal, Belgium-Luxembourg, Greece, and other countries. Canada was the principal source of granite imports, supplying over 40 percent of the imports by value. Smaller quantities of granite were imported from Italy, Sweden, Norway, and other countries. Other substantial dimension stone imports included slate from Italy and Portugal.

Exports of marble and other dimension stones to Canada totaled 436,000 cubic feet. In addition small quantities were shipped to Latin America, Europe, and India.

WORLD REVIEW

Canada.—Unique curved, marble-faced precast panels were used in the new Toronto City hall. An unusual vertical effect was achieved by using thin strips of split-faced marble. A total of 1.3 million pieces of marble were used in 4,203 panel units.[6]

Ireland.—Marble sales were increasing rapidly. A wide variety of colors were available from Tyrone, Derry, Sligo, and Galway.[7]

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[6] Concrete Products. Precasting with Marble Strips. V. 67, No. 9, September 1964, pp. 46–47.

[7] Mine and Quarry Engineering (London). Irish Marble. V. 30, No. 3, March 1964, p. 110.

TECHNOLOGY

Research on jet-flame piercing of 22 rock types indicated that structural weaknesses, soft materials, and schistosity in rocks slowed down the process. Rocks of the granite, quartz-rich metamorphic, nepheline syenite, and dolostone types were pierced easily.[8]

Details of the methods used in quarrying and processing slate at a quarry in North Wales were published. In addition to the regular production of roofing slates, sills, and cladding panels, bricks and tiles are made from waste slate.[9]

CRUSHED AND BROKEN STONE

Production of crushed and broken stone in 1964 was 723 million tons valued at $1,037 million, a record high. The average value of stone was $1.44 per ton, compared with $1.42 per ton in 1963. Continued record expenditures for road and building construction were the prime reasons for the continued growth in crushed stone demand, but nonconstruction requirements such as agricultural stone were also greater.

As readily accessible sand and gravel resources in some metropolitan areas were depleted, the slow trend to crushed stone for concrete and roadstone continued. Some large stone producers had large facilities for manufacturing precast concrete building components at their crushing plant sites. Installation of larger automatic or semiautomatic processing equipment was an important cost-cutting factor. Increasingly stringent and diverse aggregate specifications require more exacting treatment and concomitantly more screening and washing equipment and increased use of rotor-type impact breakers.

Price.—Average prices for crushed and broken stone continued to be relatively stable. Yearend prices quoted for 20 U.S. cities in Engineering News-Record averaged $2.60 per ton for 1½-inch stone and $2.69 per ton for ¾-inch stone. Lowest stone prices were quoted for New Orleans, the highest for Seattle.

Size of Plants.—A total of 3,213 plants reported production, but the 360 largest producers accounted for 53 percent of the commercial production. The total number of plants operated increased by 190 from those of 1963. The greatest number of new operations, 38, were in the 25,000- to 50,000-short-ton class.

Transportation.—Truck transportation increased 4 percent, and rail and waterway transportation respectively increased 9 and 17 percent.

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[8] Soles, James A., and Lorant B. Geller. Experimental Studies Relating Mineralogical and Petrographic Features to the Thermal Piercing of Rocks. Mines Branch Technical Bulletin, TB 53, Jan. 28, 1964. Department of Mines and Technical Surveys (Ottawa, Canada), 13 pp.

[9] Houston, W. J. Dinorwic Slate. Mining and Minerals Engineering (London), v. 1, No. 3, November 1964, pp. 90–96.

TABLE 15.—Crushed and broken stone sold or used by producers in the United States, by uses

(Thousand short tons and thousand dollars)

Use	1963		1964	
	Quantity	Value	Quantity	Value
Agriculture	26,216	$44,412	27,047	$46,485
Cement	93,299	99,688	97,950	102,486
Concrete and roadstone	439,325	598,786	455,981	628,331
Fill	7,736	8,606	1,416	946
Filtration	70	146	183	394
Flux	27,630	41,026	31,979	46,633
Glass	1,768	5,745	1,635	5,219
Lime and dead-burned dolomite	22,619	37,687	25,299	43,601
Mineral food	619	3,796	684	4,077
Poultry grit	896	7,251	861	6,391
Railroad ballast	11,727	14,054	14,170	16,801
Refractory	1,180	6,337	600	5,237
Riprap	30,200	35,982	39,495	49,780
Roofing granules, aggregates, and chips	1,965	9,337	2,369	12,407
Stone sand	3,201	4,557	3,536	5,270
Terrazzo	382	4,913	421	5,547
Other uses [1] and unspecified	16,917	49,467	19,098	57,760
Total	685,750	971,790	722,724	1,037,365

[1] Includes some uses listed separately in the Limestone and Sandstone sections.

TABLE 16.—Crushed stone sold or used by Government-and-contractor producers in the United States, by uses [1]

(Thousand short tons and thousand dollars)

Use	1963		1964	
	Quantity	Value	Quantity	Value
Concrete and roadstone	47,214	$57,174	42,508	$50,045
Riprap	15,880	16,110	23,220	26,774
Agricultural (limestone)	330	495	355	524
Other uses	3,902	5,532	521	677
Total	67,326	79,311	66,604	78,020

[1] Figures represent tonnages reported by States, counties, municipalities, and other Government agencies, produced either by themselves or by contractors expressly for their consumption, often with publicly owned equipment; they do not include purchases from commercial producers.

Granite.—Production and value of crushed and broken granite increased 15 percent compared with 1963. The average value reported in 1964 was $1.46 per ton, compared with $1.47 per ton the previous year. Production was reported in 28 States, but Georgia, North Carolina, Virginia, and South Carolina produced 77 percent of the total. A granite crushing and screening operation which incorporated a complete remote control system and closed circuit television was described.[10]

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[10] Mine and Quarry Engineering (London). Industrial Television at Pyx Granite. V. 30, No. 5, May 1964, pp. 190–197.

TABLE 17.—Crushed stone for concrete and roadstone sold or used by producers in the United States, by States

(Thousand short tons and thousand dollars)

State	1963		1964	
	Quantity	Value	Quantity	Value
Alabama	[1] 6,318	[1] $7,929	[1] 8,539	[1] $10,771
Alaska	W	W	W	W
Arizona	1,173	1,568	676	926
Arkansas	8,549	12,548	9,007	14,784
California	14,192	18,348	15,510	19,321
Colorado	470	1,119	694	1,268
Connecticut	4,937	7,862	5,413	8,762
Delaware	W	W	W	W
Florida	27,237	31,761	[1] 27,270	[1] 30,590
Georgia	[1] 14,239	[1] 19,740	[1] 17,149	[1] 23,362
Hawaii	3,433	5,994	4,706	7,863
Idaho	768	895	771	1,156
Illinois	29,105	37,356	31,615	41,524
Indiana	13,408	17,657	15,789	20,305
Iowa	15,529	20,425	17,714	24,126
Kansas	9,159	12,209	9,671	12,908
Kentucky	20,557	29,231	17,210	23,762
Louisiana	[1] 3,870	[1] 6,019	[1] 3,931	[1] 5,292
Maine	318	716	663	1,450
Maryland	10,269	17,999	10,290	18,313
Massachusetts	4,294	7,086	5,180	8,620
Michigan	3,882	4,639	4,593	5,464
Minnesota	[1] 2,735	[1] 3,342	[1] 2,507	[1] 3,060
Mississippi	----------	----------	W	W
Missouri	[1] 17,178	[1] 23,296	[1] 18,032	[1] 24,814
Montana	4,738	4,774	5,458	5,454
Nebraska	1,661	2,834	1,842	3,247
Nevada	41	35	62	72
New Hampshire	W	W	W	W
New Jersey	9,714	20,383	10,379	22,004
New Mexico	1,695	2,897	[1] 766	[1] 1,221
New York	17,383	32,066	18,281	32,678
North Carolina	15,349	22,524	16,958	25,954
North Dakota	W	W	27	48
Ohio	[1] 19,036	[1] 24,611	[1] 18,993	[1] 24,941
Oklahoma	10,337	10,727	9,952	10,148
Oregon	13,656	17,161	[1] 11,819	[1] 14,046
Pennsylvania	28,425	41,028	28,983	42,279
Rhode Island	332	502	W	W
South Carolina	[1] 5,126	[1] 7,512	[1] 5,242	[1] 7,652
South Dakota	1,929	3,326	1,108	1,778
Tennessee	[1] 21,741	[1] 26,708	[1] 21,660	[1] 28,111
Texas	29,033	32,105	25,746	30,248
Utah	27	90	[1] 156	[1] 297
Vermont	1,746	2,333	1,582	2,161
Virginia	19,670	28,483	21,615	32,519
Washington	8,948	10,271	7,709	9,745
West Virginia	3,691	5,985	[1] 2,256	[1] 3,459
Wisconsin	10,223	9,763	10,905	10,726
Wyoming	488	785	835	1,295
Undistributed	2,716	4,144	6,717	9,807
Total	439,325	598,786	455,981	628,331

W Withheld to avoid disclosing individual company confidential data; included with "Undistributed."

[1] To avoid disclosing individual company confidential data, total is somewhat incomplete, the portion not included being combined as "Undistributed."

TABLE 18.—Number and production of commercial crushed-stone plants in the United States, by size of operation

Annual production (short tons)	1963				1964			
	Number of plants	Production		Cumulative total, thousand short tons	Number of plants	Production		Cumulative total, thousand short tons
		Thousand short tons	Percent of total			Thousand short tons	Percent of total	
Less than 25,000	871	7,253	1.2	7,253	987	8,121	1.2	8,121
25,000 to 50,000	307	11,188	1.8	18,441	345	12,408	1.9	20,529
50,000 to 75,000	242	14,994	2.4	33,435	259	16,019	2.4	36,548
75,000 to 100,000	195	16,669	2.7	50,104	193	16,753	2.6	53,301
100,000 to 200,000	535	76,363	12.4	126,467	497	71,317	10.9	124,618
200,000 to 300,000	251	61,290	9.9	187,757	267	64,989	9.9	189,607
300,000 to 400,000	165	57,451	9.3	245,208	176	60,942	9.3	250,549
400,000 to 500,000	129	57,601	9.3	302,809	129	57,622	8.8	308,171
500,000 to 600,000	89	48,777	7.9	351,586	103	55,448	8.5	363,619
600,000 to 700,000	64	41,262	6.7	392,848	69	44,283	6.7	407,902
700,000 to 800,000	46	34,211	5.5	427,059	36	26,635	4.1	434,537
800,000 to 900,000	33	27,985	4.5	455,044	41	34,978	5.3	469,515
900,000 tons and over	96	163,380	26.4	618,424	111	186,605	28.4	656,120
Total	3,023	618,424	100.0	618,424	3,213	656,120	100.0	656,120

TABLE 19.—Crushed stone sold or used in the United States, by methods of transportation

Method of transportation	1963		1964	
	Thousand short tons	Percent of total	Thousand short tons	Percent of total
Commercial:				
Truck	416,864	61	435,999	60
Rail	82,578	12	89,653	13
Waterway	51,348	7	60,268	8
Unspecified	67,634	10	70,200	10
Total commercial	618,424	90	656,120	91
Government-and-contractor: Truck [1]	67,326	10	66,604	9
Grand total	685,750	100	722,724	100

[1] Entire output of Government-and-contractor operations assumed to be moved by truck.

TABLE 20.—Granite (crushed and broken stone) sold or used by producers in the United States, by uses

(Thousand short tons and thousand dollars)

Use	1963		1964	
	Quantity	Value	Quantity	Value
Concrete and roadstone	41,756	$60,881	46,909	$68,169
Railroad ballast	1,987	2,376	2,604	3,327
Riprap	1,843	3,469	3,339	5,581
Fill	520	632	345	223
Stone sand	1,138	1,019	1,292	1,134
Poultry grit	184	2,035	182	1,524
Other uses [1]	612	425	725	859
Total	48,040	70,837	55,396	80,817

[1] Includes stone used for agriculture, roofing granules, and unspecified uses.

TABLE 21.—Granite (crushed and broken stone) sold or used by producers in the United States in 1964, by States

State	Short tons	Value	State	Short tons	Value
California	3,981,373	$4,174,753	Virginia	7,232,820	$11,691,174
Colorado	482,706	818,734	Washington	384,866	489,255
Georgia	16,730,786	23,295,442	Wisconsin	603,034	177,802
Minnesota	509,938	671,225	Wyoming	655,227	960,376
Montana	190,422	184,750	Other States [1]	4,856,927	8,267,074
New Jersey	990,554	1,895,679			
New Mexico	70	140	Total	55,395,799	80,817,234
North Carolina	12,675,535	19,219,515	Puerto Rico	104,800	257,600
South Carolina	6,101,541	8,971,315			

[1] Includes Alaska, Arizona, Connecticut, Delaware, Maine, Maryland, Massachusetts, Nevada, New Hampshire, New York, Oregon, Pennsylvania, Rhode Island, Texas, and Vermont.

Basalt and Related Rocks (Traprock).—Production of crushed basaltic-type rock for railroad ballast increased 6 percent; production of this rock for all other uses declined. Total value of output decreased 2 percent. The leading producer States, Oregon, New Jersey, Washington, Connecticut, and Massachusetts accounted for 68 percent of the sales. Fused cost basalt liming and flooring components were of increasing interest in the United States. This manufactured product has long been used in Europe, but it has been introduced into the United States only in the last 10 years. It requires an alkali-type basalt which is heated to 1,300 to 1,400° C. The melt is then cast in heated molds and slowly annealed to a devitrified product with exceptional resistance to abrasion and corrosion. It is known in Europe under names such as *basalt fondu* (French) and *Schmelzbasalt* (German).

Marble.—Most crushed marble is sold as facing aggregate, terrazzo or roofing granules. Production increased 12 percent and value 29 percent.

TABLE 22.—Basalt and related rocks (traprock) (crushed and broken stone) sold or used by producers in the United States, by uses

(Thousand short tons and thousand dollars)

Use	1963		1964	
	Quantity	Value	Quantity	Value
Concrete and roadstone	61,661	$93,717	56,907	$92,618
Railroad ballast	1,784	2,735	1,887	2,846
Riprap	8,094	9,931	5,051	7,243
Fill	537	346	72	52
Other uses [1]	789	4,189	2,128	5,537
Total	72,865	110,918	66,045	108,296

[1] Includes stone used for concrete products, dam construction, filler, filtration, poultry grit, road base (including stabilized), rock wool, roofing granules, and unspecified uses.

TABLE 23.—Basalt and related rocks (traprock) (crushed and broken stone) sold or used by producers in the United States in 1964, by States

State	Short tons	Value	State	Short tons	Value
Arizona	40, 814	$36, 370	North Carolina	2, 055, 197	$3, 285, 377
California	2, 281, 548	3, 144, 267	Oregon	15, 410, 363	17, 993, 260
Colorado	5, 535	5, 535	Pennsylvania	3, 579, 063	6, 965, 261
Connecticut	5, 289, 093	8, 647, 576	Virginia	2, 554, 958	4, 405, 082
Hawaii	2, 755, 110	5, 559, 498	Washington	8, 610, 894	11, 022, 718
Idaho	765, 017	1, 142, 923	Other States [1]	3, 126, 315	7, 274, 344
Maryland	4, 029, 720	7, 709, 306			
Massachusetts	4, 711, 981	7, 659, 137	Total	66, 044, 939	108, 295, 920
Minnesota	87, 000	190, 000	American Samoa	37, 180	113, 500
New Jersey	10, 699, 390	23, 173, 890	Panama Canal Zone	67, 968	223, 000
New Mexico	42, 941	81, 376	Wake Island	68, 550	341, 720

[1] Includes Alaska, Montana, Nevada, New York, Texas, and Wisconsin.

TABLE 24.—Marble (crushed and broken stone) sold or used by producers in the United States,[1] by uses

(Thousand short tons and thousand dollars)

Use	1963		1964	
	Quantity	Value	Quantity	Value
Terrazzo	367	$4, 768	406	$5, 277
Other uses [2]	1, 385	8, 797	1, 557	12, 171
Total	1, 752	13, 565	1, 963	17, 448

[1] Produced by the following States in 1964, in order of tonnage: Georgia, Alabama, Missouri, Texas, California, New York, Arizona, Tennessee, North Carolina, Washington, Vermont, Virginia, Wisconsin, Maryland, Colorado, New Jersey, Montana, Wyoming, Nevada, and Utah.

[2] Includes stone used for acid neutralization, agriculture, asphalt filler, cast stone, mineral food, roofin chips, roadstone, stucco, whiting (excluding marble whiting made by companies that purchase marble), and unspecified uses.

Limestone.—Limestone, because of its nearly universal availability and diversified uses, was the leading type of crushed stone, accounting for 71 percent of all crushed stone produced and 61 percent of the value in 1964. The average value reported for crushed limestone was $1.36 per ton in 1964. Fifty-nine percent was used in concrete and roadstone, and 18 percent, in cement manufacture.

TABLE 25.—Limestone and dolomite (crushed and broken stone) sold or used by producers in the United States, by uses

(Thousand short tons and thousand dollars)

Use	1963		1964	
	Quantity	Value	Quantity	Value
Concrete and roadstone	292,976	$380,893	302,311	$397,481
Flux	27,185	39,322	31,454	44,511
Agriculture	25,956	44,195	26,791	46,147
Railroad ballast	4,923	6,410	5,536	7,032
Riprap	10,690	13,229	9,943	11,509
Alkali manufacture	2,955	3,282	3,254	3,617
Cement—portland and natural	86,842	92,646	91,862	95,423
Coal-mine dusting	539	2,268	525	2,279
Fill material	383	296	742	471
Filler (not whiting substitute):				
Asphalt	1,994	5,012	1,745	5,065
Fertilizer	457	1,133	430	1,127
Other	419	1,921	374	2,045
Filtration	62	117	71	139
Glass manufacture	1,492	4,781	1,420	4,437
Lime and dead-burned dolomite	21,450	36,024	24,254	42,222
Limestone sand	1,759	3,234	1,852	3,420
Limestone whiting [1]	785	9,298	775	8,903
Mineral food	618	3,793	684	4,077
Paper manufacture	358	1,099	363	1,100
Poultry grit	160	1,342	134	1,190
Refractory (dolomite)	769	1,297	162	744
Sugar refining	646	1,580	852	2,298
Other uses [2]	2,125	5,472	2,755	6,230
Use unspecified	2,805	3,282	1,736	2,931
Total	488,348	661,926	510,025	694,398

[1] Includes stone for filler for abrasives, calcimine, calking compounds, ceramics, chewing gum, fabrics, floor coverings, insecticides, leather goods, paint, paper, phonograph records, plastics, pottery, putty, roofing, rubber, wire coating, and unspecified uses. Excludes limestone whiting made by companies from purchased stone.

[2] Includes stone for acid neutralization, calcium carbide, cast stone, chemicals (unspecified), concrete products, disinfectant and animal sanitation, electrical products, magnesia, magnesite, magnesium, mineral wool, oil-well drilling, patching plaster, roofing granules, stucco, terrazzo, and water treatment.

TABLE 26.—Limestone and dolomite (crushed and broken stone) sold or used by producers in the United States in 1964, by States, and uses

State	Riprap		Fluxing stone		Concrete and roadstone	
	Short tons	Value	Short tons	Value	Short tons	Value
Alabama	W	W	961,491	$1,564,160	8,538,779	$10,771,183
Alaska	-----	-----	-----	-----	-----	-----
Arizona	-----	-----	W	W	W	W
Arkansas	-----	-----	W	W	2,042,139	3,323,414
California	W	W	W	W	1,422,365	1,726,986
Colorado	W	W	W	W	411,521	744,216
Connecticut	-----	-----	W	W	-----	-----
Florida	1,000	$2,500	-----	-----	27,269,652	30,590,247
Georgia	W	W	-----	-----	2,396,150	2,958,201
Hawaii	-----	-----	-----	-----	540,275	797,653
Idaho	-----	-----	W	W	-----	-----
Illinois	585,789	859,868	505,885	734,373	31,615,459	41,524,292
Indiana	115,138	157,443	26,153	36,052	15,788,541	20,304,882
Iowa	341,588	470,734	W	W	17,714,061	24,125,705
Kansas	857,446	1,015,624	-----	-----	9,291,398	12,193,799
Kentucky	W	W	W	W	17,210,017	23,762,183
Maine	-----	-----	-----	-----	W	W
Maryland	W	W	W	W	5,848,444	9,993,278
Massachusetts	-----	-----	W	W	W	W
Michigan	W	W	12,968,649	14,791,870	4,592,591	5,463,706
Minnesota	19,338	28,336	W	W	2,371,462	2,792,226
Mississippi	644,073	644,073	-----	-----	-----	-----
Missouri	2,350,211	2,152,669	W	W	18,031,819	24,814,270
Montana	W	W	W	W	4,981	7,978
Nebraska	757,059	1,011,220	-----	-----	1,842,154	3,246,637
Nevada	-----	-----	W	W	W	W
New Jersey	-----	-----	W	W	W	W
New Mexico	166	249	W	W	716,319	1,129,722
New York	74,929	129,464	W	W	15,344,373	26,622,344
North Carolina	-----	-----	-----	-----	W	W
Ohio	191,505	235,405	4,952,184	7,668,432	18,993,480	24,941,075
Oklahoma	197,572	206,326	-----	-----	8,885,118	8,993,260
Oregon	-----	-----	W	W	W	W
Pennsylvania	6,639	10,132	5,885,117	10,375,887	21,603,654	30,764,478
Rhode Island	-----	-----	W	W	-----	-----
South Carolina	-----	-----	W	W	W	W
South Dakota	W	W	-----	-----	609,590	854,055
Tennessee	W	W	W	W	21,660,276	28,111,532
Texas	1,555,892	2,025,293	496,770	561,504	18,268,988	18,390,934
Utah	W	W	707,856	873,075	155,815	296,904
Vermont	W	W	-----	-----	W	W
Virginia	W	W	1,265,548	2,034,365	11,803,660	16,463,698
Washington	-----	-----	W	W	W	W
West Virginia	W	W	W	W	2,256,090	3,459,329
Wisconsin	101,076	138,549	10,607	13,255	10,188,926	10,353,174
Wyoming	W	W	W	W	463,276	803,744
Undistributed	2,143,526	2,421,204	3,673,294	5,858,041	4,429,689	7,156,304
Total	9,942,947	11,509,089	31,453,554	44,511,014	302,311,062	397,481,409
American Samoa	-----	-----	-----	-----	-----	-----
Guam	-----	-----	-----	-----	280,822	468,849
Puerto Rico	12,900	26,600	-----	-----	2,055,200	4,311,450
Wake Island	-----	-----	-----	-----	1,755	5,400

W Withheld to avoid disclosing individual company confidential data; included with "Undistributed."

TABLE 26.—Limestone and dolomite (crushed and broken stone) sold or used by producers in the United States in 1964, by States and uses—Continued

State	Railroad ballast		Agriculture		Miscellaneous		Total	
	Short tons	Value	Short tons	Value	Short tons	Value	Short tons	Value
Alabama	W	W	410,458	$681,164	5,404,354	$5,140,120	15,408,424	$18,272,661
Alaska	-----	-----	-----	-----	-----	-----	-----	-----
Arizona	-----	-----	-----	-----	1,508,666	1,971,971	1,800,623	2,483,623
Arkansas	-----	-----	286,334	462,481	W	W	4,663,240	6,474,553
California	-----	-----	19,342	132,375	14,132,618	20,142,070	16,308,214	22,592,088
Colorado	-----	-----	-----	-----	1,590,777	3,060,596	2,272,932	4,412,764
Connecticut	-----	-----	W	W	W	W	282,577	1,213,283
Florida	W	W	679,368	1,795,706	W	W	31,475,721	35,943,517
Georgia	W	W	W	W	W	W	3,444,297	4,657,833
Hawaii	-----	-----	W	W	W	W	1,072,437	1,533,024
Idaho	-----	-----	W	W	W	W	W	W
Illinois	370,455	$389,862	4,660,754	6,904,147	5,242,859	5,992,758	42,981,201	56,405,300
Indiana	386,380	480,664	2,466,533	3,569,398	2,880,768	2,687,568	21,663,513	27,236,007
Iowa	10,255	16,023	2,092,555	2,994,862	W	W	23,925,858	32,869,131
Kansas	W	W	466,996	760,733	W	W	13,397,984	17,244,115
Kentucky	W	W	1,795,999	2,521,667	636,041	856,200	21,868,014	29,593,537
Maine	39,230	62,768	W	W	W	W	1,047,806	1,806,848
Maryland	W	W	W	W	2,486,045	5,212,882	8,499,097	15,514,665
Massachusetts	-----	-----	236,078	768,513	W	W	737,947	2,857,903
Michigan	W	W	678,574	1,147,238	W	W	34,516,211	36,788,021
Minnesota	-----	-----	411,957	645,134	W	W	2,869,232	3,864,936
Mississippi	-----	-----	W	W	W	W	950,538	951,533
Missouri	W	W	3,303,573	5,475,150	6,792,286	11,928,884	30,545,876	44,512,193
Montana	-----	-----	-----	-----	935,556	1,367,417	1,010,971	1,486,057
Nebraska	-----	-----	196,138	320,135	971,321	1,779,782	3,766,672	6,357,774
Nevada	-----	-----	-----	-----	W	W	W	W
New Jersey	-----	-----	W	W	W	W	W	W
New Mexico	-----	-----	-----	-----	W	W	1,260,898	1,936,041
New York	477,173	815,023	338,050	1,223,715	W	W	25,826,639	37,865,490
North Carolina	W	W	6,887	13,774	W	W	3,054,646	4,896,843
Ohio	941,736	1,161,613	2,176,035	3,842,008	9,838,455	16,945,405	37,093,395	54,793,938
Oklahoma	W	W	195,250	272,782	W	W	11,372,193	12,637,593
Oregon	-----	-----	W	W	609,869	987,020	623,382	1,018,095
Pennsylvania	91,119	122,678	1,000,054	3,104,776	15,429,139	20,758,003	44,015,722	65,135,954
Rhode Island	-----	-----	W	W	W	W	W	W
South Carolina	-----	-----	W	W	W	W	W	W
South Dakota	W	W	-----	-----	472,458	726,165	1,179,551	1,734,812
Tennessee	W	W	1,551,103	2,181,411	W	W	26,407,048	34,795,912
Texas	438,085	356,295	296,761	401,137	7,190,465	9,758,068	28,246,961	31,493,231
Utah	W	W	-----	-----	1,126,090	2,658,212	2,003,925	3,860,409
Vermont	W	W	W	W	W	W	1,410,754	4,131,243
Virginia	165,982	194,735	1,038,857	1,959,948	W	W	19,248,552	28,986,039
Washington	-----	-----	24,009	94,579	1,044,611	2,216,703	1,093,320	2,363,396
West Virginia	663,994	847,182	130,419	316,646	2,275,970	4,330,705	6,986,003	12,184,703
Wisconsin	-----	-----	1,309,804	1,740,707	182,616	426,199	11,793,029	12,671,884
Wyoming	W	W	-----	-----	483,362	1,117,149	1,258,725	2,405,284
Undistributed	1,951,818	2,585,277	1,019,349	2,816,846	52,756,105	67,653,291	2,641,330	6,415,599
Total	5,536,227	7,032,120	26,791,237	46,147,032	133,990,431	187,717,168	510,025,458	694,397,832
American Samoa	-----	-----	-----	-----	120,000	120,000	120,000	120,000
Guam	-----	-----	-----	-----	188,384	399,277	469,206	868,126
Puerto Rico	-----	-----	95,500	311,900	2,183,518	1,358,619	4,347,118	6,008,569
Wake Island	-----	-----	-----	-----	-----	-----	1,755	5,400

W Withheld to avoid disclosing individual company confidential data; included with "Undistributed."

TABLE 27.—Sales of fluxing limestone, by uses

(Thousand short tons and thousand dollars)

Year	Blast furnace		Open-hearth plants		Other smelters [1]		Other metallurgical [2]		Total	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
1955–59 (average)	25,824	$35,578	6,860	$9,990	1,014	$1,326	515	$803	34,213	$47,697
1960	21,627	30,809	7,409	10,958	997	1,311	1,382	2,004	31,415	45,082
1961	18,129	25,891	6,412	10,056	896	1,205	1,761	2,573	27,198	39,725
1962	16,996	23,062	6,411	9,835	646	952	2,028	2,972	26,081	36,821
1963	18,514	26,456	5,772	8,511	741	1,162	2,158	3,193	27,185	39,322
1964	22,364	31,437	5,625	8,082	1,075	1,278	2,390	3,714	31,454	44,511

[1] Includes flux for copper, gold, lead, zinc, and unspecified smelters.
[2] Includes flux for foundries and for cupola and electric furnaces.

TABLE 28.—Shell sold or used by producers in the United States, by uses

(Thousand short tons and thousand dollars)

Use	1963		1964	
	Quantity	Value	Quantity	Value
Concrete and road material	11,821	$17,277	12,738	$18,529
Cement	5,278	5,847	5,042	5,921
Lime	1,169	1,663	1,045	1,379
Poultry grit	552	3,874	545	3,677
Other uses [1]	199	759	123	651
Total	19,019	29,420	19,493	30,157

[1] Includes whiting, asphalt filler, other filler, and mineral food.

TABLE 29.—Shell sold or used by producers in the United States in 1964, by States

State	Short tons	Value	State	Short tons	Value
Florida	1,680,927	$2,418,476	Other States [1]	2,363,576	$5,433,255
Louisiana	5,459,044	7,227,803	Total	19,493,493	30,156,612
Texas	9,989,946	15,077,078			

[1] Includes Alabama, California, Maryland, Mississippi, New Jersey, Pennsylvania, and Virginia.

American Iron and Steel.—Institute figures indicate that 58 percent of limestone for flux was consumed by iron blast furnaces, 22 percent in making iron ore agglomerates, and the balance in steel making. An average of 0.274 ton of limestone per ton of pig iron was required in blast furnaces, compared with 0.284 ton of limestone in 1963. Respective Canadian requirements were 0.198 and 0.209 ton. The Institute also reported a 96-percent increase in the amount of lime used in the various basic oxygen processes for steelmaking. In 1964, 47 percent of lime used for steelmaking was for the basic oxygen process, 38 percent for open-hearth, and the balance for electric and bessemer.

A report was issued on limestone aggregate quality control.[11]

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[11] Turnbull, W. J. Some Requirements for Quality Control of Limestone Base Course Aggregates. National Limestone Institute, Inc., Washington, D.C., 1964, 20 pp.

Shell.—Output of shell increased 2 percent in volume and 3 percent in value. A new cement plant in Louisiana utilized shell, but an older plant in Texas was forced to suspend operation due to lack of suitable shell.

Calcareous Marl.—Marl produced for cement decreased 9 percent in tonnage and value. Agricultural marl decreased 12 percent in quantity and value. The average value of marl for all purposes was $0.86 per ton.

Sandstone, Quartz, and Quartzite.—Use in concrete and roadstone accounted for 58 percent of the production of these rock types. Average value reported for such stones was $1.57 per ton in 1964.

Crushed and Broken Slate.—Production of crushed slate increased 52 percent in 1964. Average value reported was $4.05 per ton.

TABLE 30.—Calcareous marl sold or used by producers in the United States,[1] by uses

(Thousand short tons and thousand dollars)

Use	1963		1964	
	Quantity	Value	Quantity	Value
Agriculture [2]	260	$178	228	$156
Cement	904	811	815	743
Total	1,164	989	1,043	899

[1] Produced by the following States in 1964, in order of tonnage: Mississippi, Virginia, Michigan, Indiana, Minnesota, Wisconsin, West Virginia, Nevada, and Ohio.

[2] Includes marl used in mineral food.

TABLE 31.—Sandstone, quartz, and quartzite (crushed and broken stone) [1] sold or used by producers in the United States, by uses

(Thousand short tons and thousand dollars)

Use	1963		1964	
	Quantity	Value	Quantity	Value
Concrete and roadstone	17,239	$27,595	16,163	$25,393
Railroad ballast	991	1,115	1,369	1,490
Riprap	6,020	5,140	6,961	9,231
Refractory stone (ganister)	411	5,040	438	4,493
Abrasives	63	405	56	287
Ferrosilicon	46	254	98	612
Filtration	8	29	110	195
Flux	442	1,704	522	2,122
Foundry	36	159	44	173
Glass	276	964	215	782
Other uses [2]	3,034	4,167	1,762	6,694
Total	28,566	46,572	27,738	51,472

[1] Includes ground sandstone, quartz, and quartzite. Friable sandstone is reported in the chapter on sand and gravel.

[2] Includes cement, fill, filler, porcelain, pottery, roofing granules, stone sand, terrazzo, tile, and unspecified.

TABLE 32.—Sandstone, quartz, and quartzite (crushed and broken stone) sold or used by producers in the United States in 1964, by States

State	Short tons	Value	State	Short tons	Value
Alabama	24,557	$48,039	Oklahoma	1,270,511	$1,552,335
Arizona	774,121	1,463,859	Pennsylvania	3,310,343	9,571,960
Arkansas	9,872,053	11,745,391	South Dakota	920,361	1,702,349
California	3,063,338	6,095,420	Texas	1,302,740	1,747,966
Colorado	70,639	314,693	Utah	966,136	2,490,549
Illinois	600	6,000	Virginia	431,945	688,071
Kansas	626,414	1,076,907	Washington	80,062	397,726
Minnesota	47,073	107,229	West Virginia	494,201	919,689
Montana	208,241	561,308	Wyoming	229,392	229,392
New Mexico	6,724	10,086	Other States [1]	2,786,488	6,915,302
New York	644,210	1,326,810			
North Carolina	114,186	203,001	Total	27,737,663	51,472,075
Ohio	493,328	2,297,993			

[1] Includes Connecticut, Georgia, Idaho, Indiana, Maryland, Missouri, Nevada, New Hampshire, Oregon, Tennessee, and Wisconsin.

TABLE 33.—Slate (crushed and broken stone) sold or used by producers in the United States,[1] by uses

(Thousand short tons and thousand dollars)

Use	1963		1964	
	Quantity	Value	Quantity	Value
Granules [2]	596	$2,638	295	$1,848
Flour	113	639	141	798
Lightweight aggregates	W	W	703	1,963
Other uses	40	33	W	W
Total	749	3,310	1,139	4,609

W Withheld to avoid disclosing individual company confidential data: included with granules.

[1] Produced by the following States in 1964 in order of tonnage: Virginia, Georgia, Pennsylvania, Arkansas, Vermont, and California.

[2] 1963 includes crushed slate used for lightweight aggregates: 1964 includes "Other uses."

Miscellaneous Stone.—The average value of miscellaneous crushed stone was $1.24 per ton. Local use for concrete and roadstone accounted for 53 percent of total production.

FOREIGN TRADE

Crushed stone imports were mostly marble or granite chips and chalk or whiting from Europe. The most important export item was 1.27 million tons of crushed limestone to Canada.

TABLE 34.—Miscellaneous stone (crushed and broken stone) sold or used by producers in the United States, by uses

(Thousand short tons and thousand dollars)

Use	1963		1964	
	Quantity	Value	Quantity	Value
Concrete and roadstone	13,872	18,423	20,953	26,141
Railroad ballast	2,042	1,418	2,774	2,106
Riprap	3,553	4,213	14,201	16,216
Fill	4,402	6,139	200	153
Other uses [1]	1,378	4,060	1,754	4,653
Total	25,247	34,253	39,882	49,269

[1] Includes stone used for agriculture, filtration, flux, roofing granules, stone sand, terrazzo, and unspecified uses.

TABLE 35.—Miscellaneous varieties of stone (crushed and broken stone) sold or used by producers in the United States in 1964, by States

State	Short tons	Value	State	Short tons	Value
Arizona	288, 655	$585, 009	Oklahoma	1, 338, 604	$646, 071
Arkansas	5, 605, 831	6, 843, 924	Pennsylvania	1, 353, 599	1, 889, 059
California	19, 433, 947	23, 769, 985	Washington	58, 084	34, 938
Colorado	349, 704	716, 783	Wyoming	8, 332	47, 486
Hawaii	1, 442, 300	1, 606, 066	Other States [1]	2, 374, 584	4, 714, 888
Kansas	98, 902	79, 644			
Missouri	560, 137	452, 036	Total	39, 881, 918	49, 268, 501
Montana	5, 490, 519	5, 694, 125	Panama Canal Zone	84, 740	125, 540
New Mexico	1, 447, 599	2, 132, 047	Puerto Rico	900, 900	1, 903, 600
North Dakota	31, 121	56, 440			

[1] Includes Alaska, Connecticut, Louisiana, Maine, Maryland, Massachusetts, Nevada, New Hampshire, New Jersey, New York, Rhode Island, Texas, Utah, Vermont, and Virginia.

TABLE 36.—U.S. imports for consumption of stone and whiting, by classes

Class	1963		1964	
	Quantity	Value	Quantity	Value
Marble, breccia, and onyx:				
Sawed or dressed, over 2 inches thick----cubic feet	5, 331	$35, 736	10, 371	$145, 324
In blocks, rough, etc----do	114, 256	852, 286	104, 137	813, 561
Slabs and paving tiles----superficial feet	5, 669, 565	5, 539, 576	7, 475, 465	6, 531, 942
All other manufactures	----------	4, 870, 859	----------	4, 708, 814
Total	----------	11, 298, 457	----------	12, 199, 641
Granite:				
Rough	139, 282	634, 944	144, 907	656, 170
Dressed, monumental, paving blocks, manufactured	----------	1, 529, 107	----------	1, 615, 210
Total	----------	2, 164, 051	----------	2, 271, 380
Quartzite----short tons	5, 853	90, 125	70, 959	252, 420
Slate	----------	1, 069, 082	----------	1, 400, 619
Travertine stone (unmanufactured)----cubic feet	144, 034	426, 024	112, 019	391, 386
Stone (other):				
Dressed: Travertine, sandstone, limestone, etc	----------	1, 377, 724	----------	3, 378, 985
Rough (monumental or building stone)----cubic feet	6, 882	11, 172	1, 581	3, 443
Rough (other)----short tons	1, 141, 776	1, 404, 787	1, 001, 019	1, 417, 665
Marble chip or granite----do	24, 173	246, 947	20, 826	227, 342
Crushed or ground, n.s.p.f	----------	573, 068	----------	938, 744
Total	----------	3, 613, 698	----------	5, 966, 179
Whiting:				
Chalk or whiting, precipitated----short tons	2, 132	145, 680	3, 283	264, 516
Whiting, dry, ground, or bolted----do	11, 256	168, 568	11, 019	170, 161
Whiting, ground in oil (putty)----do	17	1, 907	----------	----------
Total	----------	316, 155	----------	434, 677
Grand total	----------	18, 977, 592	----------	22, 916, 302

Source: Bureau of the Census.

TABLE 37.—U.S. exports of stone

Year	Building and monumental stone		Crushed, ground, or broken				Other manufactures of stone (value)
			Limestone		Other		
	Cubic feet	Value	Short tons	Value	Short tons	Value	
1955-59 (average)	394,463	$1,131,139	987,728	$1,509,346	161,049	$3,119,659	$470,598
1960	431,262	1,250,365	926,197	1,779,799	153,106	2,658,669	477,401
1961	435,173	1,595,805	790,912	1,596,122	128,149	3,026,785	429,604
1962	534,919	1,795,048	621,177	1,546,663	114,744	2,166,167	501,389
1963	452,167	1,669,098	762,658	1,752,930	110,949	2,095,217	584,582
1964	441,312	2,027,016	1,369,728	2,079,240	105,504	2,013,078	676,766

Source: Bureau of the Census.

TABLE 38.—U.S. exports of slate, by uses [1]

(Value)

Use	1955-59 (average)	1960	1961	1962	1963	1964
Roofing	$9,162	W	W	$15,096	W	W
Structural (including floors and walkways) and granules and flour	185,083	$47,811	$9,154	16,321	$20,081	$17,263
Other uses [2]	111,956	100,247	73,918	84,639	56,228	43,312
Total	306,201	148,058	83,072	116,056	76,309	60,575

W Withheld to avoid disclosing individual company confidential data; included with "Other uses."
[1] Figures collected by the Bureau of Mines from shippers of products named.
[2] Includes electrical slate, school slate, blackboards, and billiard tabletops.

WORLD REVIEW

U.S.S.R.—The Soviet Union was reported to be substituting for increasing amounts of metal by using fused cast basalt in applications such as tubing and blades in superphosphate mixers. For the latter use, 1 ton of cast stone was said to replace 2 to 8 tons of metal and last 10 times as long.[12]

United Kingdom.—Articles were published describing modern production practices at large crushed stone operations in Yorkshire and Lancashire.[13]

TECHNOLOGY

Progress in the development of tests by which the relative effectiveness of limestones of varying chemical composition and varying degrees of fineness is measured was reviewed. The research, sponsored by agricultural experiment stations and limestone industry laboratories, indicates that the EDTA procedure may be of considerable value in obtaining a numerical rating of reactivity.[14]

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[12] Steel. Cast Stone Replaces Metal. V. 155, No. 18, November 2, 1964, p. 38.

[13] Houston, W. J. Recent Developments at a Yorkshire Limestone Quarry. Quarry Managers J. (London). V. 48, No. 7, July 1964, pp. 289-292.

Quarry Managers Journal (London). Quarrying Gritstone in North Lancashire. V 48, No. 4, April 1964, pp. 127-130.

[14] Hunter, Albert S., Harlin Kinney, Colin W. Whittaker, J. H. Axley, Michael Peech, and Joseph E. Steckel. A Collaborative Study of the Ethylenediaminetetraacetate (EDTA) Method for Rating Agricultural Limestones. I. Reproductibility of Ratings and Correlations With Chemical and Physical Characteristics of Materials. Agronomy J., v. 55, No. 7, July 1963, pp. 351-354.

Whittaker, Colin W., J. H. Axley, Michael Peech, J. E. Steckel, E. O. McLean, and Albert S. Hunter. A Collaborative Study of the Ethylenediaminetetraacetate (EDTA) Method for Rating Agricultural Limestones. II. Relationship of Ratings and of Calcium Carbonate Content of Limestones to Their Reactivity in the Soil. Agronomy J., v. 55, No. 7, July 1963, pp. 355-358.

Mining and Processing.—Reports were published on the methods of mining high-calcium limestone underground in Virginia and on the relative breaking abilities of six types of explosives when used in limestone.[15]

Improvements in the flotation methods used by the Permanente Cement Co. to beneficiate limestone for the manufacture of cement were reported. In addition to upgrading the limestone, the froth flotation process resulted in an increased quarry life and reduced stripping ratio. A flow sheet of the circuit was shown.[16]

A general description of all the various types of rock crushing machines was given.[17]

The salient features of an Ohio quarry which worked three dolomite formations to produce a wide variety of products were described. Products included concrete aggregate to meet specifications of Ohio, West Virginia, and Kentucky, ballast, roadstone, stone sand, flux stone, flagstone, rock dust and filler.[18]

A deposit of chemical grade limestone, averaging 98.5 percent calcium carbonate, was mined by underground methods from a depth of 960 feet.[19]

A broad survey of the equipment and techniques used in the separation and collection of dusts generated by crushing and grinding operations was published.[20]

Although no recognized test procedures for evaluating wetting agents were used in dust-suppression installations, a suitable wetting agent was compounded which was suitable for 99 percent of all materials that require dust control. Among the dusts selected for testing and produced by crushing or grinding operations were those of slag, limestone, dolomite, granite, basalt, shale, and talc.[21]

Radial stackers were used at a North Carolina quarry to stockpile up to nine different products. The rock quarried was a biotite granite, and the plant was designed so that all or any part of the output could be crusher-run rock. In addition, stabilized base material, asphalt screenings, and stone sand were produced. Automatic centralized controls allowed three men to direct all processing operations.[22]

Metallurgical grade limestone, 1 by 3 inches in size, was crushed to make sinter sand for the steel industry. The sinter sand produced was 85 to 100 percent minus ⅛ inch.[23]

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[15] Atchison, Thomas C., and Joseph M. Pugliese. Comparative Studies of Explosives in Limestone. BuMines Rept. of Investigations 6395, 1964, 25 pp.
Eilertsen, N. A. Mining Methods and Costs, Kimballton Limestone Mine, Standard Lime and Cement Co., Giles County, Va. BuMines Inf. Circ. 8214, 1964, 50 pp.

[16] Kleiber, John C., and George M. Meisel. Floating Limestone at Permanente. Min. Eng., v. 16, No. 3, March 1964, pp. 39–44.

[17] Mitchell, Ronald J. Crushing Roundup. Rock Products Mining and Processing, v. 67, No. 3, March 1964, pp. 59–92.

[18] Trauffer, Walter E. Davon, Inc. Pit and Quarry, v. 57, No. 2, August 1964, pp. 84–88, 132.

[19] Mitchell, Ronald T. Going Underground for Limestone. Rock Products Mining and Processing, v. 67, No. 4, April 1964, pp. 77–8.

[20] Merriman, A. D. The Separation, Collection and Handling of Grit and Dust in Industrial Plant. Quarry Manager's J. (London), v. 48, No. 9, September 1964, pp. 357–372.

[21] Reilly, R. H. The Use of Water Sprays for Dust Suppression in Quarry Plant. Quarry Manager's J. (London), v. 48, No. 8, August 1964, pp. 313–324.

[22] Trauffer, Walter E. Superior's Pomona, N.C., Crushed Granite Plant. Pit and Quarry, v. 56, No. 12, June 1964, pp. 84–89, 144, 146.

[23] Herod, Buren C. Varied Markets Readily Served by Expanded Carbon Limestone Operations. Pit and Quarry, v. 57, No. 1, July 1964, pp. 76–81.

Portable Plants.—Increased demand was noted for mobile and semiportable crushing plants which could be stationed close to the quarry face and fed directly by power shovel. A typical mobile installation comprised an apron feeder, heavy duty vibrating bar grizzly to extract dirt, single rotor impact breaker, belt conveyor, single unit chassis with pneumatic tires and air brakes, and diesel power units.

Strontium

By E. C. Peterson[1]

◆

CONSUMERS of strontium minerals continued in 1964 to depend on imports from the United Kingdom and Mexico for their supply. The domestic strontium-mining industry has been inactive since 1959.

LEGISLATION AND GOVERNMENT PROGRAMS

The General Services Administration offered for sale, at its warehouse in Point Pleasant, W. Va., about 12,500 short tons of celestite ore; 9,632 tons were of Spanish origin, and the remainder was obtained from Mexico. Bids were received in Washington, D.C., until May 8, but none were accepted.

There were no contracts negotiated in 1964 by the U.S. Department of Agriculture, Commodity Credit Corporation (CCC) for acquisition of foreign-produced strontium under the barter program; however, 10,670 tons of celestite was delivered by the United Kingdom and Mexico during the year under earlier barter agreements.

DOMESTIC PRODUCTION

Imported celestite was used to produce strontium chemicals by E. I. du Pont de Nemours & Co., Inc., at Grasselli, N.J.; Foote Mineral Co. at Exton, Pa.; and Inorganic Chemicals Division, FMC Corp., Modesto, Calif.

King Laboratories, Inc., Syracuse, N.Y., continued to be the only domestic strontium metal producer as well as the principal consumer.

CONSUMPTION AND USES

Strontium or strontium compounds were utilized in pyrotechnics, such as in tracer bullets, distress signal rockets and flares, military signal flares, transportation warning fuses, and fireworks. Other uses included ceramics, chemicals, depilatories, caustic soda refining, desulfurizing steel, dielectrics, drilling muds, getter alloys, greases, luminous paint, plastics, rubber filler, scavengers in metallurgy, and welding rod coatings. No new uses for strontium metal or strontium compounds were reported in 1964.

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[1] Commodity specialist, Division of Minerals.

PRICES

Prices of various strontium compounds were quoted in Oil, Paint and Drug Reporter throughout 1964 as follows: Strontium sulfate, air-floated, 90 percent, 325 mesh, bags, works, $56.70 to $66.15 per short ton; strontium carbonate, pure, drums, 5-ton lots or more, works, $0.35 per pound; drums, 1-ton lots, works, $0.37 per pound; technical-grade, drums, works, $0.19 per pound; and strontium nitrate, bags, carlots, works, $11 per 100 pounds and bags, less than carlots, works, $12 per 100 pounds. These prices have remained unchanged since 1955.

FOREIGN TRADE

Quantity and value of strontium mineral imports increased 33 and 36 percent, respectively, over the 1963 figures. The United Kingdom supplied 76 percent of the 1964 imports.

TABLE 1.—U.S. imports for consumption of strontium minerals,[1] by countries

Country	1963		1964	
	Short tons	Value	Short tons	Value
Italy	11	$2,700	16	$4,200
Mexico	6,476	104,867	5,278	66,824
United Kingdom	9,745	264,457	16,323	435,474
Total	16,232	372,024	21,617	506,498

[1] Strontianite or mineral strontium carbonate and celestite or mineral strontium sulfate.

Source: Bureau of the Census.

WORLD REVIEW

United Kingdom and Mexico, in that order, are the free world's principal producers of strontium minerals, but in recent years production has also been reported from Argentina, Italy, and Pakistan. Strontium minerals are known to occur in many countries throughout the world, but the demand is not sufficient to warrant exploitation of these deposits. Usually small requirements in most countries are satisfied by importation of prepared strontium compounds and products.

TABLE 2.—Free world production of strontium minerals, by countries[1] [2]

(Short tons)

Country[1]	1955–59 (average)	1960	1961	1962	1963	1964
Argentina	194	NA	NA	NA	NA	NA
Italy	518	915	1,080	661	721	[e] 720
Mexico[3]	2,208	2,881	2,642	4,554	6,476	5,278
Morocco	[4] 740	----	----	----	----	----
Pakistan	607	1,491	462	323	424	[e] 260
United Kingdom	7,244	7,397	9,720	7,316	[3] 9,744	[3] 16,323
United States	[5] 2,100	----	----	----	----	----
Free world total[1]	13,611	12,684	13,904	12,854	17,365	[e] 22,600

[e] Estimate. NA Not available.

[1] Strontium minerals are produced in Germany, Poland, and the U.S.S.R., but data on production are not available; no estimates are included in the total for these countries.

[2] This table incorporates some revisions.

[3] U.S. imports.

[4] Average annual production 1957–59.

[5] Average annual production 1955–56.

TECHNOLOGY

Engineering studies contemplating construction of an isotope plant at the Atomic Energy Commission's (AEC) Hanford works in Washington State have been completed. The plant, part of the proposed diversification of the Hanford works, would include facilities for purifying as well as packaging of isotopes. Annual capacity would be 10 megacuries of strontium–90, 10 megacuries of cesium–137, 100 megacuries of cerium–144, and 30 megacuries of promethium–147. Studies indicate that this plant would permit considerable reductions in isotope prices because of its volume production.

What is believed to be the first observation of superconductivity in an oxide-type semiconductor has been demonstrated by researchers at the National Bureau of Standards Institute for Basic Standards using strontium oxide as the semiconductor. Because the superconducting properties of the compounds can be varied with treatment, it may be possible to tailor-make materials for compact superspeed computers, high-field industrial magnets, and possibly other applications.[2]

An analytical method for the determination of calcium-strontium ratios in powder samples was discussed. After the prepared sample is irradiated with white radiation from a tungsten target x-ray tube, the intensities of the characteristic K lines of calcium and strontium are measured with a flow proportional counter. Calcium and strontium contents are determined by interpolation on standard curves versus the resulting ratios.[3]

A report was published describing the conditions required for the extraction and purification of strontium from fission product solutions.[4]

Patents were granted relevant to commercial techniques in the recovery of strontium values from aqueous feed [5] and waste solutions [6] containing strontium together with iron values, rare earth fisson product values and other impurities.

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[2] Technical News Bulletin (Dept. of Commerce). Superconductivity Observed in the Semiconductor Strontium Titanate. V. 48, No. 8, August 1964, pp. 126–127.

[3] Chemistry and Industry (London). Analytical Method for the Determination of Calcium-Strontium Ratios in Powder Samples. V. 29, July 28, 1964, p. 1290.

[4] Chemistry and Industry (London). The Extraction and Purification of Strontium from Fission Products Solutions. V. 8, Feb. 22, 1964, p. 327.

[5] Horner, Donald E., and Russel P. Wischow (assigned to the United States as represented by the Atomic Energy Commission). Process for Recovery of Strontium Values From Fission Product Waste Solutions. U.S. Pat. 3,122,414, Feb. 25, 1964.

[6] Junsen, George Jr., Gerald L. Richardson, Allison M. Platt, and Lane A. Bray (assigned to the United States as represented by the Atomic Energy Commission). Strontium Recovery Process. U.S. Pat. 3,154,500, Oct. 27, 1964.

Sulfur and Pyrites

By Paul M. Ambrose[1]

◆

THE SULFUR industry in 1964 was marked by the initiation of transocean shipments of liquid sulfur, an increase in the price of sulfur, and a worldwide increase in demand that grew faster than production.

Deliveries of liquid sulfur started in 1959; in 1964, about 90 percent of shipments of domestic sulfur was in liquid form. The first shipment (25,350 tons) of liquid sulfur overseas in May was delivered by the Sulphur Export Corp. (Sulexco) in the *Naess Texas* from Beaumont, Tex., to Rotterdam, Netherlands. Later in the year Sulexco acquired the services of the sister ship the *Naess Louisiana.* At the end of 1964 there were 8 ships, with a combined capacity of 139,300 tons, carrying molten Frasch sulfur to North American and European markets. Other ships were planned to start operating in 1965 and 1966. Liquid sulfur from Lacq, France, was transported in railway cars to Bayonne and delivered by an 11,000-ton ship to Rouen, France, Immingham, England, and to Rotterdam, Netherlands.

Prices of sulfur increased $2 per ton during the year.

After several years of overproduction of Frasch sulfur in the United States, a near balance between production and shipments was reached in 1963 when 4.88 million tons was produced and 4.99 million tons was shipped. In 1964, domestic production increased to 5.23 million tons while shipments were 5.86 million tons. At the same time stocks of Frasch sulfur in Mexico and of recovered sulfur in Canada were being decreased.

In the United States production of recovered sulfur started in 1943 and was more than 1 million tons in 1964.

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[1] Commodity specialist, Division of Minerals.

TABLE 1.—Salient sulfur statistics

(Long tons, sulfur content)

	1955–59 (average)	1960	1961	1962	1963	1964
United States:						
Production	5,429,617	5,037,292	5,477,493	5,025,418	4,881,927	5,228,365
All forms	6,831,537	6,660,541	7,172,479	6,757,211	6,643,802	7,092,734
Imports, pyrites and sulfur	558,786	884,838	966,417	1,185,073	[r] 1,460,680	[1] 1,582,211
Exports, sulfur	1,628,339	1,786,543	1,596,043	1,553,986	1,612,637	1,928,092
Stocks Dec. 31: Producer, Frasch and recovered sulfur	4,101,193	3,777,799	4,813,521	4,934,238	4,682,496	4,402,905
Consumption, apparent, all forms [2]	5,620,700	5,862,000	5,893,000	6,243,600	[r] 6,607,000	7,084,000
World: Production:						
Sulfur, elemental	8,683,000	[r] 10,400,000	[r] 11,500,000	[r] 12,000,000	[r] 12,600,000	13,800,000
Pyrites	7,620,000	[r] 8,900,000	[r] 8,700,000	[r] 9,000,000	[r] 9,000,000	9,000,000

[r] Revised.

[1] Includes estimated 120,000 tons of sulfur in pyrites imports.

[2] Measured by quantity sold, plus import, minus exports.

DOMESTIC PRODUCTION

Native Sulfur.—The 10 Frasch process mines in operation in 1964 were the 4 mines of Freeport Sulphur Co. at Grand Ecaille, Garden Island Bay, and Lake Pelto in Louisiana, and Grand Isle, 7 miles off the Louisiana coast in the Gulf of Mexico; 4 mines of Texas Gulf Sulphur Co. at Newgulf, Fannett, Moss Bluff, and Spindletop in Texas; 1 mine of Duval Corp. at Orchard Dome, Tex.; and 1 mine of Jefferson Lake Sulphur Co. (merged with Occidental Petroleum Corp. during the year), at Long Point Dome in Texas.

Production of 155,550 tons by the Duval Corp. at Orchard Dome was 18,450 tons less than in 1963 because of the lower sulfur content of the formation mined during the year. An increase in the domestic market absorbed most of the 25-percent increase in sales.[2]

Production and sales by Freeport Sulphur Co. were the highest in the company's history. Approximately 2.75 million tons were produced from the four mines. This production was only 50,000 tons less than the sales of 2.8 million tons. Except for temporary shutdowns during Hurricane Hilda, production might have been greater than sales. Melting equipment was provided at Joliet, Ill., so that the 200,000-ton stockpile of solid sulfur could be marketed in the liquid state if needed. About one-fourth of Freeport's sulfur was sold overseas. Additional barges were acquired to service inland waterway system markets and arrangements were made in 1964 for an ocean-going tanker, the SS *Louisiana Brimstone*, to supply coastal terminals from Florida to Maine.[3]

Production of sulfur by Texas Gulf Sulphur Co. was more than 2.4 million long tons in 1964. Frasch processed sulfur was the major source of production but facilities for the recovery of sulfur from sour natural gases were increased. Sulfur recovery plants were operated at Worland, Wyo., and at Okotoks and Whitecourt in Alberta, Canada. Capacity was increased from 725 to 1,225 tons per day at the

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[2] Duval Corp. Annual Report 1964, p. 4.

[3] Freeport Sulphur Co. Annual Report 1964, pp. 4, 6, 8.

Whitecourt plant at a cost of $2 million. Production in Canada by Texas Gulf Sulphur Co. increased from 316,000 tons in 1963 to 327,000 tons in 1964. The SS *Marine Texan*, with a carrying capacity of 23,760 tons of sulfur, replaced the SS *Marine Sulphur Queen*, lost in 1963. The company's number of regional distribution terminals for liquid sulfur was increased to 12.[4]

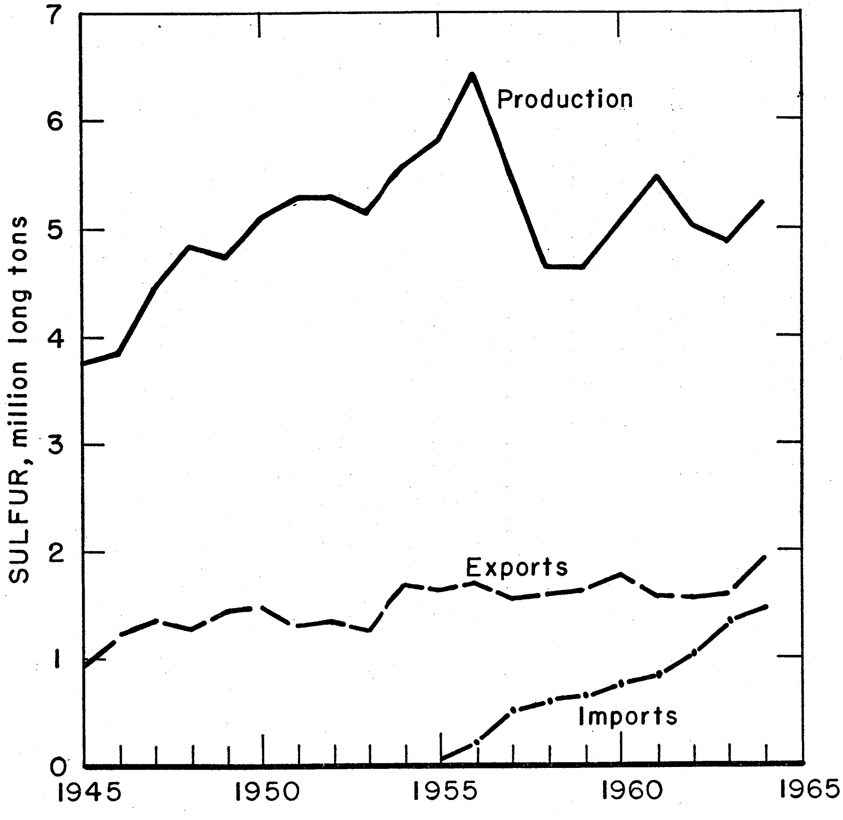

FIGURE 1.—Domestic production, imports, and exports of native sulfur.

Recovered Sulfur.—Production of recovered sulfur from sour natural and refinery gases exceeded 1 million tons, and was 8 percent greater than in 1963. In 1964, 72 sulfur recovery plants were operated by 46 companies in Arkansas, California, Delaware, Illinois, Indiana, Louisiana, Michigan, Minnesota, Mississippi, Montana, New Jersey, New Mexico, North Dakota, Ohio, Pennsylvania, Texas, Virginia, and Wyoming. The five leading producing States produced about three-fourths of the total. In descending order of production they were Texas, California, Delaware, Wyoming, and New Jersey.

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[4] Texas Gulf Sulphur Co. Annual Report 1964, pp. 2, 5, 7.

TABLE 2.—Production of sulfur and sulfur-containing raw materials by producers in the United States

(Long tons)

	1955–59 (average)		1960		1961		1962		1963		1964	
	Gross Weight	Sulfur Content	Gross Weight	Sulfur Content	Gross Weight	Sulfur Content	Gross Weight	Sulfur Content	Gross Weight	Sulfur Content	Gross Weight	Sulfur Content
Native sulfur or sulfur ore:												
Frasch-process mines	5,370,190	5,370,190	4,942,935	4,942,935	5,385,468	5,385,468	4,984,578	4,984,578	4,881,512	4,881,512	5,228,207	5,228,207
Other mines	205,354	59,427	379,067	94,357	400,015	92,025	162,186	40,840	1,371	415	794	158
Total	---------	5,429,617	---------	5,037,292	---------	5,477,493	---------	5,025,418	---------	4,881,927	---------	5,228,365
Recovered elemental sulfur:												
Brimstone	541,983	540,008	769,319	766,566	861,413	858,169	902,124	899,598	949,567	946,753	1,024,649	1,021,358
Paste	224	102	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------
Total	---------	540,110	---------	766,566	---------	858,169	---------	899,598	---------	946,753	---------	1,021,358
Pyrites (including coal brasses)	1,034,995	423,554	1,016,263	416,213	987,309	398,519	915,890	379,046	824,800	343,566	847,493	353,831
Byproduct sulfuric acid (basis 100 percent) produced at Cu, Zn, and Pb plants	1,064,594	347,850	1,056,890	345,075	1,016,731	331,963	1,088,397	355,362	1,089,523	355,730	1,119,976	365,706
Other byproduct sulfur compounds [1]	104,400	90,406	114,359	95,395	126,923	106,335	115,670	97,787	136,509	115,826	143,689	123,474
Total	---------	6,831,537	---------	6,660,541	---------	7,172,479	---------	6,757,211	---------	6,643,802	---------	7,092,734

[1] Hydrogen sulfide and liquid sulfur dioxide. In addition, a quantity of acid sludge is converted to H_2SO_4 but it is excluded from the above figures.

TABLE 3.—Sulfur produced and shipped from Frasch mines in the United States

Year	Produced (long tons)			Shipped	
	Texas	Louisiana	Total	Long tons	Approximate value (thousands)
1955–59 (average)	3,225,067	2,145,123	5,370,190	5,283,336	$133,495
1960	2,678,643	2,264,292	4,942,935	5,002,638	115,494
1961	2,777,674	2,607,794	5,385,468	5,082,585	117,884
1962	2,621,974	2,362,604	4,984,578	4,917,466	107,069
1963	2,412,653	2,468,859	4,881,512	4,995,023	99,014
1964	2,488,975	2,739,232	5,228,207	5,859,289	117,228

TABLE 4.—Sulfur ore (10 to 70 percent S) produced and shipped in the United States[1]

Year	Produced (long tons)	Shipped	
		Long tons	Value (thousands)
1955–59 (average)	205,354	172,621	$1,544
1960	379,067	181,422	1,732
1961	400,015	177,549	1,694
1962	162,186	150,550	1,439
1963	1,371	1,371	15
1964	794	794	8

[1] California and Nevada.

New recovered sulfur plants reporting production in 1964 were Atlantic Refining Co. in Philadelphia County, Pa., and at Riverton Dome, Fremont County, Wyo.; Climax Chemical Co., Lea County, N. Mex.; Pan American Petroleum Corp., Edgewood plant in Van Zandt County, N. Mex.; and Warren Petroleum Corp. at the Sand Hills plant in Crane County, Tex. Reported data do not include a former producer, Texaco Inc., at the Silver Tip plant in Park County, Wyo.

TABLE 5.—Recovered sulfur produced and shipped in the United States

(Long tons)

Year	Production		Shipments		
	Gross weight	Sulfur content	Gross weight	Sulfur content	Value (thousands)
1955–59 (average)	541,983	540,008	513,185	511,255	$13,663
1960	769,319	766,566	778,079	775,214	18,163
1961	861,413	858,169	834,046	831,001	18,861
1962	902,124	899,598	909,964	907,340	19,599
1963	949,567	946,753	932,147	929,369	19,401
1964	1,024,649	1,021,358	993,643	990,437	21,088

Pyrites.—As in recent previous years Tennessee was the leading producing State followed in order by Pennsylvania, Colorado, Arizona, and South Carolina. Pyrite consumption by producers was 795,000 tons having a sulfur content of 329,000 tons and valued at $5,232,000. The grade of concentrates marketed was much higher than in 1963.

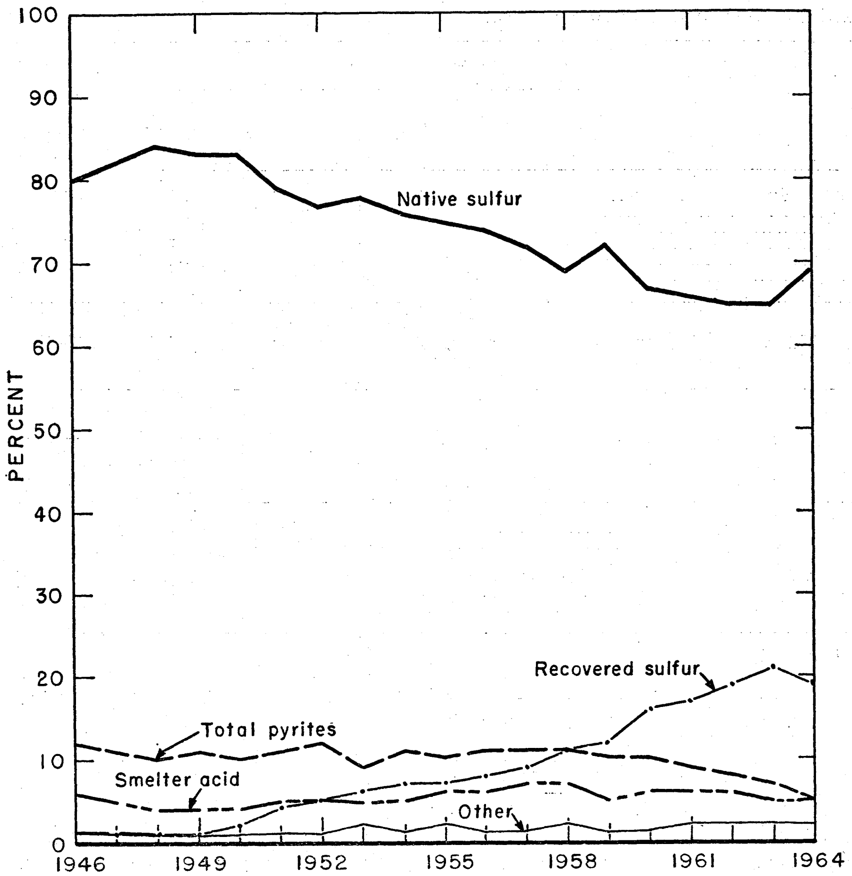

FIGURE 2.—Sulfur supply sources as a percent of total apparent consumption based on sulfur content.

TABLE 6.—Production and shipments of pyrites (ores and concentrates) in the United States

(Long tons)

Year	Production		Value (thousands)	Shipments		Value (thousands)
	Gross weight	Sulfur content		Gross weight	Sulfur content	
1955-59 (average)	1, 034, 995	423, 554	$8, 671	140, 678	67, 393	$982
1960	1, 016, 263	416, 213	7, 936	150, 281	72, 205	901
1961	987, 309	398, 519	7, 418	117, 957	56, 870	816
1962	915, 890	379, 046	6, 809	64, 476	31, 382	359
1963	824, 800	343, 566	5, 698	72, 618	33, 449	303
1964	847, 493	353, 831	5, 471	49, 829	23, 832	239

Byproduct Sulfur Compounds.—Copper and zinc plants in the United States produced sulfuric acid from smelting sulfide ores. Either hydrogen sulfide or sulfur dioxide was recovered from 10 plants owned by 9 companies in California, Louisiana, New Jersey, Pennsylvania, and Tennessee. The hydrogen sulfide production was from oil refineries and the sulfur dioxide was from smelter gases.

TABLE 7.—Byproduct sulfuric acid[1] (basis, 100 percent) produced at copper, zinc, and lead plants in the United States

(Short tons)

Plants	1955–59 (average)	1960	1961	1962	1963	1964
Copper[2]	394, 798	412, 845	362, 630	403, 683	358, 503	330, 273
Zinc[3]	797, 547	770, 872	776, 109	815, 322	861, 763	924, 100
Total	1, 192, 345	1, 183, 717	1, 138, 739	1, 219, 005	1, 220, 266	1, 254, 373

[1] Includes acid from foreign materials.

[2] Includes acid produced at a lead smelter. Excludes acid made from pyrite concentrates in Arizona, Montana, Tennessee, and Utah.

[3] Excludes acid made from native sulfur.

CONSUMPTION

U.S. consumption of sulfur in all forms attained a new record of 7.1 million long tons, 7 percent greater than in 1963. The increase in apparent consumption of native sulfur was 6 percent; recovered sulfur consumption increased 9 percent and pyrite consumption increased 9 percent.

Estimates of free world consumption of all forms of sulfur prepared late in 1964 by the two leading producing companies of the world were essentially in agreement at 21.7 and 21.775 million tons compared with 19.62 and 19.725 million tons by the same estimators for 1963. The greatest percentage increases were of recovered sulfur from western Canada and Frasch sulfur from Mexico. The 1964 reduction in free world sulfur stocks was about 1 million tons.[5]

STOCKS

On December 31, producer stocks of Frasch sulfur totaled 4,301,000 tons, 8.6 percent less than at yearend 1963. Stocks comprised 3,454,000 tons at the mines and 847,000 tons elsewhere. Producer stocks of recovered sulfur were 102,000 tons, an accumulation of 13,000 tons during the year. Pyrite stock data were unavailable.

Since approximately 90 percent of the elemental sulfur shipped by producers was in the liquid state, storage capacity for this form of sulfur became increasingly more important. At the end of the year there were 28 producer-owned distribution terminals with 49 tanks having a combined capacity of 462,000 tons. There were also 2 producer-storage terminals near the mines with 18 tanks with a combined storage capacity of 165,000 tons. Consumers at 26 locations had 32 storage tanks with a capacity of approximately 165,000 tons.

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[5] Gittinger, L. B., Jr. Sulphur—1964. Eng. and Min. J., v. 165, No. 2, February 1965, pp. 150–152.
Levitsky, Serge L. Sulfur. Min. Eng., v. 17, No. 2, February 1965, pp. 131–132.

TABLE 8.—Production of new sulfuric acid[1] (100 percent H_2SO_4) by geographic divisions and States

(Short tons)

Division and State	1960	1961	1962	1963	1964
New England[2]	192, 664	179, 341	184, 142	183, 956	192, 629
Middle Atlantic:					
New York and New Jersey	1, 681, 302	1, 652, 868	1, 684, 590	1, 749, 165	1, 826, 309
Pennsylvania	754, 703	770, 272	797, 207	877, 120	941, 270
Total	2, 436, 005	2, 423, 140	2, 481, 797	2, 626, 285	2, 767, 579
North Central:					
Illinois	1, 355, 647	1, 399, 349	1, 464, 064	1, 562, 320	1, 696, 501
Indiana	485, 297	456, 372	(3)	(3)	(3)
Michigan	324, 318	307, 979	331, 901	355, 824	347, 386
Ohio	742, 287	684, 312	661, 535	659, 090	674, 819
Other[3]	715, 137	781, 046	1, 361, 113	1, 474, 984	1, 597, 865
Total	3, 622, 686	3, 629, 058	3, 818, 613	4, 052, 218	4, 316, 571
South:					
Alabama	312, 996	242, 996	319, 218	350, 396	436, 631
Delaware and Maryland	1, 119, 452	1, 077, 644	1, 114, 025	1, 016, 809	1, 043, 077
Florida	2, 272, 039	2, 518, 215	3, 087, 431	3, 822, 364	4, 405, 556
Georgia	337, 140	345, 775	384, 010	420, 765	442, 942
Kentucky and Tennessee	997, 379	1, 024, 717	(4)	(4)	(4)
Louisiana	595, 232	598, 534	675, 159	699, 985	763, 214
North Carolina	131, 221	133, 115	140, 591	144, 864	156, 176
South Carolina	142, 652	149, 493	143, 250	154, 281	168, 423
Texas	1, 593, 303	1, 585, 307	1, 885, 553	1, 925, 948	2, 273, 982
Virginia	460, 098	448, 839	467, 122	495, 366	518, 032
Other[4]	584, 181	606, 031	1, 759, 087	1, 802, 141	1, 908, 632
Total	8, 545, 693	8, 730, 666	9, 975, 446	10, 832, 919	12, 116, 665
West[5]	2, 288, 142	2, 095, 837	2, 322, 500	2, 342, 159	2, 565, 621
Total United States	17, 085, 190	17, 058, 042	18, 782, 498	20, 037, 537	21, 959, 065

[1] Includes data for Government-owned and privately operated plants.
[2] Includes data for plants located in Maine, Massachusetts, and Rhode Island.
[3] Includes data for plants located in Iowa (1961–64), Indiana, Kansas, Minnesota, Missouri, and Wisconsin. Data for Indiana for prior years were reported separately.
[4] Includes data for plants located in Arkansas, Kentucky, Mississippi, Oklahoma, Tennessee, and West Virginia. Data for Kentucky and Tennessee for prior years were reported separately.
[5] Includes data for plants located in Arizona, California, Colorado, Hawaii, Idaho, Montana, Nevada New Mexico, Utah, Washington, and Wyoming.

Source: U.S. Department of Commerce.

TABLE 9.—Apparent consumption of native sulfur in the United States

(Long tons)

	1955–59 (average)	1960	1961	1962	1963	1964
Apparent sales to consumers[1][2]	5, 311, 406	5, 129, 300	4, 854, 809	4, 873, 021	r 5, 050, 923	5, 599, 018
Imports	395, 886	607, 235	648, 910	745, 772	863, 385	890, 604
Total	5, 707, 292	5, 736, 535	5, 503, 719	5, 618, 793	r 5, 914, 308	6, 489, 622
Exports:						
Crude	1, 604, 139	1, 775, 526	1, 585, 531	1, 537, 419	1, 603, 438	1, 920, 392
Refined	24, 200	11, 017	10, 512	16, 567	9, 199	7, 000
Total	1, 628, 339	1, 786, 543	1, 596, 043	1, 553, 986	1, 612, 637	1, 927, 392
Apparent consumption	4, 078, 953	3, 949, 992	3, 907, 676	4, 064, 807	r 4, 301, 671	4, 562, 230

r Revised.
[1] Production adjusted for net change in stocks during year.
[2] Includes native sulfur from mines that do not use Frasch process.

TABLE 10.—Apparent consumption of sulfur in all forms in the United States[1]

(Long tons)

	1955–59 (average)	1960	1961	1962	1963	1964
Native sulfur	4,079,000	3,950,000	3,907,700	4,064,800	[r] 4,301,700	4,562,200
Recovered sulfur:						
Sales	517,000	775,200	831,000	907,300	929,400	987,600
Imports	(2)	134,100	182,600	294,700	487,800	571,200
Pyrites:						
Domestic production	423,560	416,200	398,500	379,000	343,600	353,800
Imports	162,900	146,000	134,900	144,600	93,000	[e] 120,000
Total pyrites	586,460	562,200	533,400	523,600	436,600	473,800
Smelter-acid production	347,860	345,100	332,000	355,400	335,700	365,700
Other productions [3]	90,380	95,400	106,300	97,800	115,800	123,500
Grand total	5,620,700	5,862,000	5,893,000	6,243,600	6,607,000	7,084,000

[e] Estimate. [r] Revised.

[1] Crude sulfur or sulfur content.

[2] Data included with imports on table 9. Not separately available before 1960.

[3] Hydrogen sulfide and liquid sulfur dioxide. In addition, a quantity of acid sludge is converted to H_2SO_4, but is excluded from the above figure.

TABLE 11.—Liquid sulfur regional storage and transshipment terminals in operation in 1964

Producer controlled terminals	Number of storage tanks	Total storage capacity (thousand long tons)
Freeport Sulphur Co.:		
Baton Rouge, La	1	6.5
Bucksport, Maine	2	20.0
Charleston, S.C	1	10.0
Everett, Mass	1	10.0
Joilet, Ill	3	30.0
Le Moyne, Ala	2	9.8
Nitro, W. Va	2	18.0
Tampa, Fla	4	40.0
Tuscaloosa, Ala	1	3.8
Warners, N.J	2	12.5
Wellsville, Ohio	2	20.0
Total	21	180.6
Gulf Sulphur Corp.:		
Baltimore, Md	1	10.0
Tampa, Fla	2	22.0
Total	3	32.0
Pan American Sulphur Co.:		
Baltimore, Md	1	10.0
Newark, N.J	1	10.0
Tampa, Fla	4	40.0
Total	6	60.0
Texas Gulf Sulphur Co.:		
Baltimore, Md	2	24.0
Carteret, N.J	2	26.0
Cincinnati, Ohio	3	16.8
Jacksonville, Fla	1	11.0
Marseilles, Ill	1	10.0
Nashville, Tenn	1	8.0
Newell, Pa	1	10.0
Norfolk, Va	2	20.8
Paulsboro, N.J	2	24.0
Savannah, Ga	1	11.0
Tampa, Fla	2	19.5
Wilmington, N.C	1	8.0
Total	19	189.1

PRICES

For the first 6 months the published prices for Frasch sulfur were unchanged from 1963. Prices f.o.b. gulf ports were $25 per long ton for bright sulfur and $24 for dark sulfur. Mine prices were $1.50 below port prices. In 1964 price increases on new business came first in the overseas markets. A domestic price increase of $2 per ton became effective on new business on July 1, and as of January 1, 1965, on business under contract. Posted prices at yearend 1964 were $27.50 per long ton f.o.b. gulf ports for bright sulfur to be exported, $25.50 per long ton f.o.b. mines, and $27 per long ton f.o.b. gulf ports for domestic markets. The published price for acid grade on dark sulfur at any point, or for any market, was $1 less than that for bright sulfur. Prices for sulfur delivered from storage terminals in or near major consuming areas included transportation costs and terminal charges and tended to reflect competitive conditions within the distribution area.

FOREIGN TRADE

Both imports and exports of sulfur for 1964 increased, with the increase in exports much greater than the increase in imports. Exports to the United Kingdom decreased sharply, due to the loss of the National Sulphuric Acid contract, but exports to the European continent increased sharply.

Information from Canadian and U.S. consumers indicate that 1964 imports of pyrites totaled about 250,000 tons. Official Census Bureau data reported a much lower figure which was being examined.

TABLE 12.—U.S. imports for consumption and exports of sulfur

Year	Imports		Exports			
			Crude		Crushed, ground, refined, sublimed and flowers	
	Long tons	Value (thousands)	Long tons	Value (thousands)	Long tons	Value (thousands)
1955-59 (average)	395,886	$9,176	1,604,139	$44,087	24,200	$1,929
1960	741,370	15,453	1,775,526	40,880	11,017	1,413
1961	831,517	17,152	1,585,531	35,370	10,512	1,254
1962	1,040,473	20,310	1,537,419	35,496	16,567	1,799
1963	1,351,216	23,942	1,603,438	33,531	9,199	1,057
1964	1,462,211	26,100	1,920,392	39,651	7,700	1,287

Source: Bureau of the Census.

TABLE 13.—U.S. imports for consumption of sulfur by countries

Country	1963		1964	
	Long tons	Value (thousands)	Long tons	Value (thousands)
North America:				
Canada	480,355	$6,650	568,372	$7,779
Mexico	863,385	17,101	890,604	18,249
Total	1,343,740	23,751	1,458,976	26,028
South America: British Guiana			284	4
Europe:				
France	7,431	184	2,863	63
Germany, West	45	7	25	4
United Kingdom			(1)	(1)
Total	7,476	191	2,888	67
Asia: India			63	1
Grand total	1,351,216	23,942	1,462,211	26,100

[1] Less than ½ unit.

Source: Bureau of the Census.

TABLE 14.—U.S. exports of sulfur by countries

Destination	Crude				Crushed, ground, refined, sublimed, and flowers			
	1963		1964		1963		1964	
	Long tons	Value (thousands)	Long tons	Value (thousands)	Pounds	Value (thousands)	Pounds	Value (thousands)
North America:								
Canada	141,710	$3,811	136,207	$3,790	2,090,309	$191	2,060,973	$230
Central America	6,757	159	18,408	374	669,419	32	853,584	32
Mexico	441	14	197	4	324,800	57	404,151	80
West Indies	16,798	360	1,000	19	19,500	1	5,590	(1)
Total	165,706	4,344	155,812	4,187	3,104,028	281	3,324,298	342
South America:								
Argentina	8,001	147	45,301	912	118,900	27	197,950	41
Bolivia					43,780	2		
Brazil	134,843	2,855	128,723	2,591	656,578	94	1,002,823	163
Chile	2,000	41	8,874	183	22,655	6	20,000	3
Colombia	1,476	32			1,956,371	63	152,106	23
Ecuador	40	1	76	3	101,210	8	90,900	9
Paraguay			159	5	66,623	1	224,100	3
Peru	13,370	270	15,726	319	268,015	24	228,525	29
Uruguay	4,716	93	10,176	203	2,700	(1)	10,000	2
Venezuela	5,293	150	162	5	744,703	33	763,964	65
Total	169,739	3,589	209,197	4,221	3,981,535	258	2,690,368	338
Europe:								
Austria	16,464	309	38,215	778				
Belgium-Luxembourg	49,500	986	46,000	932	3,100	1	60,050	12
Czechoslovakia	38,000	776	28,500	567				
France	53,719	1,079	52,710	1,059			148,635	13
Germany, West	72,200	1,460	106,910	2,192	64,850	6	40,500	3
Ireland	40,707	838						
Netherlands	116,495	2,270	456,562	9,203	8,718	(1)	34,878	1
Norway	1,800	35			42,200	1	80,000	2
Spain	5,612	117	5,406	110	39,900	9	98,900	20
Sweden	4,627	92			67,200	9	78,000	13
Switzerland	35,600	711	25,650	501				
United Kingdom	247,875	4,844	21,170	464				
Yugoslavia			7,000	128	22,050	3	22,050	3
Other	587	10	33,090	646	17,642	2	1,800	1
Total	683,186	13,527	821,213	16,580	265,660	31	564,813	68
Asia:								
Bahrain	130	5	40	1	120,385	12	89,910	1
India	247,755	5,340	296,400	5,832	5,047,680	157	2,954,539	130
Indonesia	600	14	3,000	79	424,469	14	159,400	7
Iraq	1,833	62	8,020	301	322,000	5	332,992	5
Israel	55,750	1,089	60,900	1,201	192,521	12	337,952	17
Japan					20,100	5	31,200	7
Jordan					1,544,164	35	1,125,367	25
Korea, South	4,407	102	9,142	201	1,031,109	30		
Lebanon			3,000	62	305,200	7	460,400	17
Malaysia			1,000	20	4,500	1	26,600	4
Pakistan	3,055	61			148,830	6	489,564	12
Philippines	627	14	109	3	877,915	32	1,308,025	64
Saudi Arabia	1,419	55	2,808	87	592,797	10	732,398	14
Turkey					205,975	15	380,175	25
Other	5,376	100	7,634	158	398,053	11	412,201	15
Total	320,952	6,842	392,053	7,945	11,235,698	352	8,840,723	343
Africa:								
South Africa, Republic of	3,632	86	11,169	426	1,258,500	58	1,013,481	97
Tunisia	29,250	554	9,600	203				
Other	5,428	103	8,478	172	83,800	3	164,220	7
Total	38,310	743	29,247	801	1,342,300	61	1,177,701	104
Oceania:								
Australia	129,562	2,545	165,244	3,127	378,538	48	409,116	58
New Zealand	95,983	1,941	147,626	2,790	298,077	26	240,152	34
Total	225,545	4,486	312,870	5,917	676,615	74	649,268	92
Grand total	1,603,438	33,531	1,920,392	39,651	20,605,836	1,057	17,247,171	1,287

[1] Less than ½ unit.

Source: Bureau of the Census.

WORLD REVIEW

NORTH AMERICA

Canada.—Cansulex Ltd., the Canadian sulfur marketing organization, announced a contract to supply Hungary with 100,000 tons of sulfur in 1965. Sales of 60,000 tons in France, Belgium, Netherlands, and West Germany were assured. Australia remained the largest overseas market for Canadian sulfur. It was anticipated that 1964 sales would be 100,000 tons greater than production, thus decreasing stocks by that amount.[6]

The Alberta Sulphur Research Ltd., a new sulfur research group, was formed by eight natural gas producers to increase the technical knowledge of sulfur and its compounds. The member companies include Shell Canada Ltd., Standard Oil of California, Canadian Fina Oil Ltd., Home Oil Co. Ltd., Hudson Bay Oil and Gas Co. Ltd., Imperial Oil Ltd., Pacific Petroleum Ltd., and Texas Gulf Sulphur Co. It is likely that cooperation will exist between this group and two other groups of similar interests, The Research Council of Alberta and the Sulphur Institute, Washington, D.C.[7]

The Independent Petroleum Association of Canada predicted that over the next 10 years western Canada's natural gas industry will require an average of at least three new processing plants per year. It was expected that there would be a need for 20 or more plants between 1966 and 1972 to process new gas reserves, and 8 or 10 plants to handle established reserves.[8] Sulfur production from sour natural gas is closely tied to gas production.

A sale of more than 300,000 long tons of Canadian sulfur to Australia by Cansulex Ltd., and East Asiatic Co. Ltd. of Canada was the largest Canadian sale of sulfur to be exported over a 3-year period.

New markets in 1964 included Brazil, Greece, Hong Kong, Hungary, Italy, Lebanon, Mozambique, the Netherlands, Poland, Tunisia, and Venezuela. Canadian producers have been interested in the U.S.S.R. and Japanese markets for some time. Japanese imports were to offset sulfur shortages but the long range Japanese objective was to remain self-sufficient in sulfur. The U.S.S.R. expects to triple fertilizer production and the increased sulfuric acid needed may require further imports. Poland, expected to emerge as a large producer from sulfur ores, may help supply these needs.

EUROPE

Austria.—Sulfur was being produced in Austria from crude oil from the Soviet Union at the 25,000-barrel-per-day Schwechat refinery near Vienna. About 500,000 tons of crude oil containing 1.8 to 2.0 percent sulfur was brought to Austria from the Soviet Union in 1963. Sufficient oil was not available in early 1964 to permit starting the sulfur recovery plant completed in October 1963.[9]

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[6] European Chemical News (London). Hungary to Buy 100,000 Tons of Canadian Sulphur. V. 6, No. 152, Dec. 11, 1964, p. 6.

[7] European Chemical News (London). V. 5, No. 124, May 29, 1964, p. 8.

[8] Chemical Engineering. V. 71, No. 3, Feb. 3, 1964, p. 40.

[9] Chemical Engineering. Austrians Recover Sulfur From Soviet Petroleum. V. 71, No. 22, Oct. 26, 1964, p. 80.

TABLE 15.—World production of elemental sulfur by countries [1] [2]

(Long tons)

Country	1960	1961	1962	1963	1964 [p]
Native sulfur:					
Frasch:					
Mexico	1,261,574	1,148,494	1,350,375	1,456,656	1,635,773
United States	4,942,935	5,385,468	4,984,578	4,881,512	5,228,207
Total	6,204,509	6,533,962	6,334,953	6,338,168	6,863,980
From sulfur ores:					
Argentina	39,265	22,183	22,303	22,142	18,995
Bolivia (exports)	1,175	4,896	7,247	9,793	10,635
Canary Islands	4,000	5,000	6,000	6,900	[e] 6,900
Chile	30,901	43,994	63,228	57,861	49,693
China [e]	120,000	120,000	120,000	120,000	120,000
Colombia	8,899	9,941	10,046	12,795	11,942
Italy	79,703	68,668	53,068	41,128	28,374
Japan [3]	243,684	238,456	220,438	219,095	237,414
Mexico	[e] 17,700	25,116	26,751	28,968	25,989
Philippines	43	158	926	47	68
Poland	25,885	130,900	206,684	231,486	289,948
Spain	1,336	-------	-------	-------	-------
Taiwan	5,725	5,732	7,462	7,144	6,389
Turkey	16,830	15,506	18,247	19,123	21,849
U.S.S.R. [e]	800,000	900,000	950,000	950,000	950,000
United Arab Republic (Egypt)	3,543	8,858	[e] 6,000	4,675	[4] 4,675
United States	94,357	92,025	40,840	415	158
Total [e] [5]	1,490,000	1,690,000	1,760,000	1,730,000	1,800,000
Total native sulfur	7,700,000	8,225,000	8,100,000	8,100,000	8,650,000
Other elemental:					
Recovered:					
Austria	-------	-------	-------	-------	6,000
Bulgaria [6]	5,310	4,949	5,502	6,291	[e] 6,400
Canada (sales) [7]	244,963	352,465	620,622	1,115,968	1,438,552
China [e] [6] [8]	130,000	130,000	130,000	130,000	130,000
Finland	-------	-------	-------	37,611	67,063
France [9]	778,157	1,080,013	1,325,538	1,386,285	1,487,141
Germany:					
East	110,232	115,153	118,100	118,100	[4] 118,100
West	82,807	82,861	89,268	84,949	76,602
Iran [e] [8]	20,000	20,000	15,000	20,000	105,000
Italy [e]	3,200	2,000	2,000	2,000	2,000
Japan [8]	8,326	8,163	8,549	11,429	18,448
Mexico [9]	33,487	51,086	46,545	43,308	36,296
Netherlands [6]	30,018	27,952	30,511	34,447	[4] 34,447
Netherlands Antilles: Aruba and Curacao [e]	40,000	40,000	40,000	30,000	[4] 30,000
Norway [6]	71,254	61,156	45,175	-------	-------
Portugal [6]	10,915	8,813	6,677	2,953	[4] 2,953
South Africa, Republic of [8]	-------	2,163	1,913	1,981	5,701
Spain [6]	40,194	48,324	41,836	68,036	[4] 68,036
Sweden [10]	39,368	30,511	29,920	25,885	[4] 25,885
Taiwan [8]	876	1,968	2,130	2,310	2,780
Trinidad [e] [8]	5,000	5,000	5,000	7,000	[4] 7,000
U.S.S.R. [e]	210,000	275,000	370,000	400,000	400,000
United Arab Republic (Egypt)	2,369	2,545	2,039	2,355	2,427
United Kingdom [11]	62,402	58,405	51,929	46,600	[4] 46,600
United States	766,566	858,169	899,598	946,753	1,021,358
Total other elemental	2,700,000	3,270,000	3,890,000	4,525,000	5,140,000
World total [e] [2]	10,400,000	11,500,000	12,000,000	12,600,000	13,800,000

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[e] Estimate. [p] Preliminary.

[1] This table incorporates some revisions.

[2] Data do not add exactly to totals shown because of rounding where estimated figures are included in the detail.

[3] Includes sulfur from mixed sulfur-sulfide ore.

[4] 1963 data.

[5] In some years Iran produces mine sulfur equivalent to 250–1,500 tons of sulfur. No estimates in total.

[6] From sulfide ore.

[7] Produced from natural gas, includes a small quantity derived from treatment of nickel-sulfide matte at Port Colborne, Ontario.

[8] From refinery gases.

[9] From natural gas.

[10] From shale oil.

[11] Including sulfur recovered from petroleum refineries.

France.—England's first liquid sulfur terminal at Immingham received its initial shipment of 7,500 tons from France. The terminal was built for Société Nationale des Pétrolés d'Aquitaine (SNPA), the State-controled company developing the sulfur and petrochemical resources of the southwestern France gas fields. The Lacq sulfur is transported in railroad tank cars to the port of Bayonne where it is stored in a 24,000-ton-capacity terminal for shipment by the sulfur tanker, *President Andre Blanchard.* The 11,000-ton-capacity tanker was expected to complete 40 trips per year to Immingham, England, Rotterdam, Netherlands, and Rouen, France. Storage capacity for French deliveries was 22,000 tons at Immingham and 20,000 tons at Rotterdam, and was expected to be 13,000 tons at Rouen when completed. Annual throughput of the three terminals could be 570,000 tons but deliveries were expected to be restricted to 350,000 to 420,000 tons by transportation facilities. Present customers for Immingham liquid sulfur were within 80 miles of the terminal. Transportation from the Rotterdam terminal was to be by barge.

Greece.—The discovery of a massive pyrite deposit of 500,000 tons of 45 to 48 percent sulfur in Cyprus was announced by Hephaestus Mining Co., Ltd. Geological investigations indicate that the ore body may be substantially larger. Preliminary company studies indicated that the ore could be mined and delivered to the nearest port for $3.50 per ton. This compared favorably with a selling price of $7.69 per ton f.o.b. Cyprus port for noncupreous coarse lump pyrite.[10]

According to a trade agreement, Greece will export 10,000 tons of pyrite to Poland before September 30, 1965.

Ireland.—Europe's third terminal for receiving and storing liquid sulfur was planned for Dublin. Plants manufacturing fertilizer would use the sulfur in making sulfuric acid. Two European firms, and Freeport Sulphur Co. and Texas Gulf Sulphur Co. of the United States were cooperating in the complex.[11]

Italy.—The European Economic Community (E.E.C.) recommended the development of an additional sulfur mine, the Lucia, in Sicily. The high-grade sulfur ore would be used at Porto Empedocle. The annual output of the Sicilian sulfur mines would be limited to 750,000 tons. The Italian sulfur industry had, for several years, faced increasing competition from Frasch sulfur from Mexico and the United States.

The Sulphur Export Corp. (Sulexco), which handled overseas sales for U.S. Frasch producers, sold 13,000 tons to Ente Zolfi Italiani, an agency of the Italian Government. The Italian Government was modernizing the domestic sulfur industry so that it can compete in world markets.

Norway.—The production of sulfur as a byproduct in producing blister copper at Thambshavn, South Trøndelag County, was discontinued by Orkla Metal, A/S, Norway's only elemental sulfur producer.[12]

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[10] Bureau of Mines. Mineral Trade Notes. V. 59, No. 4, October 1964, pp. 41–42.

[11] Chemical Trade Journal and Chemical Engineer (London). Liquid Sulphur Terminal for Dublin. V. 155, No. 4043, Dec. 4, 1964, p. 772.

[12] Bureau of Mines. Mineral Trade Notes. V. 60, No. 1, January 1965, p. 47.

TABLE 16.—World production of pyrites (including cupreous pyrites)[1] [2]

(Thousand long tons)

Country [1]	1955–59 (average) gross weight	1960		1961		1962		1963		1964 [p]	
		Gross weight	Sulfur content	Gross weight	Sulfur content	Gross weight	Sulfur content	Gross weight	Sulfur content	Gross weight	Sulfur content
North America:											
Canada (sales)	961	922	391	462	228	462	236	425	218	318	157
Cuba [e]	57	18	8	20	9	26	12	33	15	30	13
United States	1,035	1,016	416	987	399	916	379	825	344	847	354
South America: Venezuela	[3] 23	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Europe:											
Bulgaria	84	117	49	120	50	140	59	128	54	144	61
Czechoslovakia	352	384	148	363	141	395	155	342	[e] 133	355	140
Finland	277	256	108	270	114	468	215	529	248	539	258
France	353	273	117	281	118	299	125	247	109	248	107
Germany:											
East	147	[e] 130	46	[e] 115	40	[e] 120	41	[e] 125	[e] 43	[4] 125	[4] 43
West	566	529	210	524	221	404	173	398	175	[e] 423	[e] 190
Greece	197	161	74	185	86	142	65	[e] 148	[e] 66	138	[e] 62
Italy	1,416	1,523	694	1,555	716	1,560	711	1,377	628	1,375	619
Norway	803	820	356	722	319	780	320	700	315	698	314
Poland	185	223	83	198	76	219	82	213	85	[4] 213	[4] 85
Portugal	650	645	297	643	296	631	290	593	273	598	269
Rumania	193	263	105	259	103	300	120	328	131	[4] 328	[4] 131
Spain	2,175	2,217	1,053	2,097	1,001	2,095	997	1,995	941	2,303	1,098
Sweden	408	406	203	431	220	370	189	396	[e] 197	[4] 396	[4] 197
U.S.S.R. [e]	2,100	2,750	1,460	2,750	1,460	2,950	1,565	3,150	1,670	3,150	1,670
United Kingdom	3	(5)	(5)	(5)	(5)	27	[e] 11	26	[e] 10	[4] 26	[4] 10
Yugoslavia	279	410	164	358	143	407	163	350	140	421	168

Asia:										
China [e]	(6)	985	440	985	440	1,080	490	1,180	530	1,280	575
Cyprus [7]	1,006	914	439	824	396	809	388	905	440	662	323
Japan [8]	3,142	3,634	1,517	3,869	1,624	3,952	1,664	3,833	1,623	[e] 3,935	[e] 1,575
Korea:											
North [e]	(6)	245	98	295	118	345	138	395	157	415	167
South	(5)	2	(5)	1	(5)	----------	----------	(5)	(5)	NA	NA
Philippines	18	25	[e] 11	51	[e] 22	55	26	57	27	31	15
Taiwan	31	42	16	47	20	45	20	46	17	46	17
Turkey	51	42	20	97	46	105	51	96	44	111	51
Africa:											
Algeria	20	38	17	48	22	42	19	37	17	60	28
Morocco	8	13	5	14	5	20	7	23	7	21	6
Rhodesia (formerly Southern)	32	49	19	58	23	50	19	65	[e] 27	81	30
South Africa, Republic of	432	492	212	440	176	434	[e] 175	412	[e] 165	426	[e] 175
Oceania: Australia	215	239	115	213	102	149	65	194	87	[e] 246	[e] 110
World total [e] [1] [2]	17,900	19,800	8,900	19,300	8,700	19,800	9,000	19,600	9,000	20,000	9,000

[e] Estimate. [p] Preliminary. NA Not available.

[1] Brazil produces pyrites, but production data are not available; no estimate is included in the total.

[2] This table incorporates some revisions. Data do not add exactly to totals shown because of rounding where estimated figures are included in the detail.

[3] Average annual production 1956–59.

[4] 1963 data.

[5] Less than ½ unit.

[6] Data not available; estimate included in total.

[7] Tons of ore mined containing pyrites in thousand long tons: 1955–59 average 1,495; 1960, 1,810; 1961, 1,842; 1962, 1,860; 1963, 2,139; and 1964, NA.

[8] Years 1960–63 include pyrrhotite, cupreous pyrites, sulfur ore, and zinc concentrates. Pyrite data covering pyrites, cupreous pyrites, and pyrrhotite only are as follows (in thousand long tons): 1960, 2,656; 1961, 2,855; 1962, 2,977; 1963, 2,954; and 1964, 2,721—includes pyrites and pyrrhotite only.

TABLE 17.—Sulfur recovery plants in Western Canada, 1964

Company	Location	H_2S content of feed (percent)	Annual capacity (long tons)
Amerada Petroleum Corp	Olds, Alberta	--------	50,000
British American Oil Co., Ltd	Pincher Creek, Alberta	10	298,000
Do	Nevis, Alberta	6	27,000
Do	Homeglen-Rimbey, Alberta	4–8	94,000
Canadian Fina Oil Ltd	Wildcat Hills, Alberta	4	46,000
Home Oil Co., Ltd	Carstairs, Alberta	1	14,000
Imperial Oil Ltd	Redwater, Alberta	3	5,000
Jefferson Lake Petrochemicals of Canada, Ltd.	Taylor Flats, British Columbia	3	115,000
Do	Coleman, Alberta	14	135,000
Petrogas Processing, Ltd	Calgary, Alberta	16	305,000
Royalite Oil Co. Ltd	Turner Valley, Alberta	4	11,000
Shell Canada, Ltd	Innisfail, Alberta	14	41,000
Do	Waterton, Alberta	22	530,000
Do	Jumping Pound, Alberta	3	36,000
California Standard Oil Co. Ltd	Nevis, Alberta	6	50,000
Steelman Gas, Ltd	Steelman, Saskatchewan	1	2,000
Texas Gulf Sulphur Co	Whitecourt, Alberta	15–20	435,000
Texas Gulf Sulphur Co. and others	Okotoks, Alberta	35	151,000
Total	--------	--------	2,345,000

TABLE 18.—Mexico: Exports of sulfur by countries

(Long tons)

Destination	1963	1964
North America:		
Canada	25,198	--------
El Salvador	3,445	--------
United States	821,477	907,800
South America:		
Brazil	12,135	12,136
Colombia	--------	1,476
Venezuela	4,921	5,500
Europe:		
Belgium	32,730	61,842
France	56,536	175,716
Germany, West	--------	12,969
Netherlands	127,365	133,111
Poland	--------	26,798
United Kingdom	130,531	254,555
U.S.S.R	--------	18,585
Asia:		
Israel	11,505	17,609
Taiwan	--------	10,344
Thailand	1,000	--------
Africa:		
Morocco	--------	3,148
South Africa, Republic of	74,933	75,169
Tunisia	--------	60,080
Oceania:		
Australia	88,543	47,577
New Zealand	44,116	22,591
Total	1,434,435	1,847,006

Poland.—An important new sulfur ore mine was started at Machow, Poland, in early January 1964. It was to be second in size only to the Polish mine in Piaseczno. The new deposits, much richer than those in Piaseczno, were near a chemical combine on the Vistula River. When the mine is completed in 1970 production is expected to be 6.5 million tons of sulfur ore per year and will replace output from deposits in Piaseczno which will have been exhausted by that time. The chemical combine in Machow, now supplying 200,000 tons per year of pure sulfur, was to be expanded to provide over 1 million tons per year in the period 1970–75.[13] Construction, expected to be completed in 1964, included the preparation of access roads and railway sidings and the sinking of 100 drainage wells. Development was to be completed by 1970. Most of the mine output was to go to the Tarnobrzeg sulfur processing works where a new plant would double the present 200,000-ton-per-year capacity of the works.[14]

United Kingdom.—The first United Kingdom ocean terminal for the storage of liquid sulfur, nearing completion at Immingham, for Société Nationale des Pétrolés d'Aquitaine, was to be ready for shipments in May 1964.[15]

ASIA

India.—Consideration was being given to mining pyrites from the extensive deposits at Amjore, Bihar. A process for the production of sulfur from Amjore pyrites was being developed from a method used in Finland. Finland and the Central Fuel Research Institute of India were working on another plan. India produced over 500,000 tons of sulfuric acid in 1963. The slowly expanding fertilizer industry consumed 60 percent of acid production.[16]

Japan.—The number of producing sulfur mines declined from 19 in 1961 to 16 in 1964. Production from the 16 mines appeared to be exceeding the 1963 rate. In the period 1961–63 the sulfur output per worker increased 35 percent. This improvement in output was especially important, because the price of Japanese sulfur was considerably above the world level. The reported value of crude sulfur imported into Japan in the first half of 1964 was $48.54 per ton.[17]

Taiwan.—Sulfur imports of 40,000 tons in 1963 were expected to be increased to 59,100 tons in 1964.[18]

AFRICA

Algeria.—Production of pyrites at Algeria's only iron pyrite mine, near Philippeville, continued to increase after a government manager and a technical director were appointed late in 1963 to operate the mine. The labor force increased from 298 at the end of 1962 to 442 at yearend 1964. Because of increased consumption, from 8,644 tons in 1962 to 23,257 tons in 1964, Algeria was unable to fulfill all of its export contracts.

United Arab Republic (Egypt).—Sulfur ores were reported to have been discovered in the Maragi and Khamsia Hills of the Magaaz area adjacent to the Siwa Oasis. Neighboring hills were being examined to determine the extent of the deposits.[19]

TECHNOLOGY

New methods or innovations of old ones for the recovery of sulfur from waste gases were being developed. In one process sodium metavanadate provided oxygen for the oxidation of hydrogen sulfide (H_2S) to sulfur and water. Sodium metavanadate with sodium salts of anthraquinone resulted in the production of sulfur from coke oven or coal gas. Cost data were given for several different sized plants with assumed recoveries of 95 percent and 98 percent from gases containing 1 percent H_2S. A flow sheet was given.[20] A British patent was issued on a process for recovering sulfur from H_2S and sulfur dioxide (SO_2). Ammonium thiosulfate was formed when the gas reacted with aqueous ammonia. It in turn reacted with H_2S to form sulfur.[21] The latter process for recovery of sulfur from gases containing H_2S was reported to be in use in Canada in a plant owned by Canadian Industries Ltd., Montreal, Quebec. Enough sodium hydroxide was added to bring the pH to 9. The reaction products were hydrogen peroxide and sulfur.[22]

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[13] East Europe Daily Press Report. Development of Sulfur Ore Mine Started. Jan. 20, 1964.

[14] Chemical Age (London). Poland to Sink New Sulphur Mine. V. 91, No. 2328, Feb. 22, 1964, p. 302.

[15] Chemical Age (London). Imatex to Operate Liquid Sulphur Terminal. V. 91, No. 2323, Jan. 18, 1964, p. 121.

[16] Bureau of Mines. Mineral Trade Notes. V. 60, No. 1, January 1965, pp. 47–48.

[17] Bureau of Mines. Mineral Trade Notes. V. 60, No. 2, February 1965, pp. 40–41.

[18] Bureau of Mines. Mineral Trade Notes. V. 60, No. 2, February 1965, p. 41.

[19] Bureau of Mines. Mineral Trade Notes. V. 59, No. 4, October 1964, p. 46.

A patent was granted for recovering sulfur from beds of elemental sulfur by partial combustion. The resulting molten sulfur could be pumped to the surface. Sulfur dioxide was also recovered.[23]

Pyrite or pyrrhotite could be roasted in a series of individual beds, each maintained at a depth of 20 to 35 cm and provided with separate supplies of gas containing oxygen. Roaster gases containing sulfur dioxide (SO_2) were withdrawn from each bed.[24] A similar procedure was used at Anglo-Vaal's Hartebeestfontein Gold Mining Co., Ltd., Transvaal, Republic of South Africa, to produce 10 percent SO_2 gas which was converted to sulfuric acid by autoxidation. The pyrite could be concentrated to 45 percent FeS_2, but it was difficult to control the bed depth with this grade of concentrate. For easier operations the assay value was maintained at about 40 percent FeS_2. Solids and gas were separated in a cyclone separator. The gases were further cleaned and cooled to 100° to 130° F. in a three stage gas scrubber before being mixed with air and fed to the autoxidation cells.[25]

The first commercial magnetic roasting of pyrites was being done by Montecatini Soc. Generale per l'Industria Mineraria e Chimica of Italy in a plant at Follonica in central Italy. The plant had a capacity to roast 1,000 metric tons per day of pyrite to produce magnetite and sulfur dioxide (SO_2). It was planned to double the capacity of the plant and produce 1,100 tons per day of 65 percent iron pellets, 2,200 tons per day of sulfuric acid, and 700,000 kw per day of electric power using steam recovered from waste heat boilers and from cooling coils at the discharge of the fluosolids roasters. Iron sulfides were roasted to hematite and SO_2 at 900° to 950° C. Excess air was used to cut down on the sulfur in the calcine. Magnetic roasting of the hematite, with fuel oil, was done at 675° C. The bottom discharge of the fluosolids magnetic roaster was treated by dry magnetic separation. Dust was collected in cyclones, water quenched, and the iron was concentrated in wet magnetic separators. A flow sheet with typical balances was published.[26] Innovations of the process were given.[27]

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[20] Ellwood, Peter. Metavanadates Scrub Manufactured Gas. Chem. Eng., v. 71, No. 15, July 20, 1964, pp. 128–130.

[21] Chemical Trade Journal and Chemical Engineer (London). Removal of Hydrogen Sulphide and Sulphur Dioxide from Waste Gas. V. 154, No. 4017, June 5, 1964, p. 825.

[22] Chemical Engineering. V. 71, No. 16, Aug. 3, 1964, p. 86.

[23] Miller, W. S. Burning Process for Recovering Sulfur from the Earth. U.S. Pat. 3,131,914, May 5, 1964.

[24] Engineering and Mining Journal. Recovering Coarse-grained Roasted Ore. V. 165, No. 4, April 1964, p. 204.

[25] Mining Magazine (London). Pyrite Roaster Plant. V. 110, No. 6, June 1964, pp. 412–413.

Control of the tensile strength of sulfur by regulating the time-temperature history of sulfur is possible. If molten sulfur is held at 187° C for 2 hours and cooled rapidly, a large percentage of the solid mass is amorphous sulfur with a tensile strength of 400 to 600 psi. If cooled slowly most of the sulfur will be the orthorhombic form with a tensile strength of 40 to 60 psi. These data explain why recovered sulfur is more difficult to grind than Frasch sulfur and suggest that amorphous sulfur would have less dust loss in handling.[28]

Pellets or large granules of sulfur were made by dropping molten sulfur from nozzles into swirling water. The sulfur droplets began to solidify on contact with the water and were forced downward in a spiral path. A recycling system forced water into the cooler at different levels. The pellets with a specific gravity of 2.1 were formed from molten sulfur with a specific gravity of 1.8.[29]

The Alberta Research Council developed a technique for producing foamed sulfur. When sulfur was heated beyond the melting point and foam-inducing agents added, the sulfur remained in the foamed state when solidified. The purpose was to decrease density so that transportation by pipeline (in suspension) would be easier.[30]

A low-cost sulfur foam that may compete with urethane and polystyrene for certain purposes is reported to have been developed by Southwest Research Institute. The foam could be used at temperatures up to 230° F, was lightweight and strong, had low shrinkage, and did not absorb much water.[31]

Surfur-impregnated fiber pipes were made by depositing fiber from a water slurry on a rotating mandrel, drying, and impregnating with liquid sulfur. The dried pipes were placed in a closed heated vessel and the pressure reduced. Liquid sulfur was pumped into the vessel with the pipe under reduced pressure. The dried pipe would absorb from 50 to 500 percent by weight of sulfur. The optimum range was found to be 200 to 400 percent in making a pipe satisfactory, after cooling, for use as underground or drainage pipes.[32]

The need to include sulfur as a plant nutrient in fertilizer was emphasized, and desirable ratios of other plant foods to sulfur were expressed. The use of elemental sulfur and soluble sulfur compounds was discussed as well as the requirements of certain crops for sulfur.[33] The behavior of elemental sulfur in acid-rock mixtures during the preparation of concentrated superphospate, and the distribution of sulfur in the final product were discussed.[34]

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[26] Engineering & Mining Journal. First Commercial Magnetic Roasting Plant Utilizes Fluid Bed Reactors. V. 165, No. 11, November 1964, pp. 104–107.

[27] Vaccari, Italo, Pierluigi Salle, and Angelo Morra (assigned to Montecatini Società Generale per l'Industria Mineraria e Chimica). Process for Treating Iron Pyrites. U.S. Pat. 3,160,496, Mar. 27, 1962.

[28] Chemical & Engineering News. Concentrates. V. 42, No. 29, July 20, 1964, p. 35.

[29] Chemical Age. Pellet Process Eases Sulphur Transport. V. 92, No. 2371 and 2372 (combined issue), Dec. 19 and 26, 1964, p. 941.

[30] Chemical Engineering. V. 71, No. 7, Mar. 30, 1964, p. 31.

[31] Product Engineering. Developments to Watch. V. 35, No. 22, Oct. 26, 1964, p. 68.

[32] Chemical Trade Journal and Chemical Engineer (London). Sulphur Impregnated Fibre Pipes. V. 154, No. 4012, May 1, 1964, p. 626.

[33] Bixby, David W., Samuel L. Tisdale, and Delbert L. Rucker. Adding Plant Nutrient Sulphur to Fertilizer. The Sulphur Institute, Tech. Bull. No. 10, October 1964, 41 pp.

[34] Wieczorek, G. A., A. V. Breen, and J. O. Hardesty. Addition of Sulfur to Concentrated Superphosphate. Farm Chemicals. V. 127, No. 12, December 1964, pp. 24–32.

The U.S. Department of Agriculture reported that the addition of sulfur to many soils in the South was necessary to maintain or increase crop growth. Results of experiments at 24 locations in 7 States indicated that crop yields would decrease on 63 percent of the soils tested in 7 years or less if sulfur were not added. Supplementary sulfur increased yields in 15 of 22 experiments with cotton, forage, and tobacco. It was concluded that sulfur in rainwater, atmosphere, insecticides, and fertilizers could not meet crop needs in the area studied.[35]

One of the findings of the Nebraska Agricultural Experiment Station was that there were only slight variations in effectiveness between elemental sulfur and calcium sulfate as sulfur sources for soils, when particle size and placement were optimum for both. Elemental sulfur particle size should be less than 0.1 millimeter diameter for best results.[36]

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[35] Jordan, Howard V. Sulfur as a Plant Nutrient in the Southern United States. U.S. Dept. of Agriculture Tech. Bull. No. 1297, February 1964, 45 pp.

[36] Sulphur Institute News. Nebraska Research Results Reported. V. 4, No. 1, January–February 1964, p. 1.

Talc, Soapstone, and Pyrophyllite

By J. Robert Wells[1]

◆

DOMESTIC production of talc, soapstone, and pyrophyllite, already at a historical summit in 1963, substantially exceeded that volume in 1964 and increased for the fourth consecutive year to establish another alltime maximum. While sales increased both in volume and in total value, there was a significant drop in the average unit value, attributable at least in part to the marketing of the material in a less finely ground condition than heretofore. World production, doubling in volume in less than 10 years, reached its alltime highest level in 1964.

TABLE 1.—Salient talc, soapstone, and pyrophyllite statistics

(Thousands short tons and thousand dollars)

	1955–59 (average)	1960	1961	1962	1963	1964
United States:						
Mine production	732	734	762	772	804	890
Value	$4,906	$5,378	$5,277	$5,278	$5,505	$6,218
Sold by producers	724	722	727	777	794	875
Value	$15,187	$16,073	$16,022	$17,882	$18,420	$18,973
Imports for consumption	24	24	27	26	26	23
Value	$816	$849	$1,055	$1,069	$1,088	$917
Exports [1]	47	60	48	47	57	74
Value [1]	$1,293	$1,893	$1,805	$2,230	$2,778	$3,391
World: Production	2,200	2,780	2,990	2,960	3,330	3,760

[1] Excludes powders—talcum (in package), face, and compact.

DOMESTIC PRODUCTION

In the United States in 1964, both production and sales of talc, soapstone, and pyrophyllite exceeded 800,000 tons, production for the second consecutive year and sales for the first time in history. New York, California, and North Carolina were the leading producing States in 1964, with an aggregate output about 8 percent higher than that of 1963. Talc and soapstone were supplied by 65 mines in 14 States, and pyrophyllite was mined at 12 sites in 3 States. North Carolina led in the production of pyrophyllite, with Pennsylvania (sericite schist) and California ranking second and third, respectively.

In Montana, plans were announced to build a dry grinding plant for processing ore from the Talc Ridge mine in Madison County. Work was started preliminary to the active exploitation of new talc ore bodies near Ashland, Jackson County, Oreg., and in the Roosevelt District of Esmeralda County, Nev.

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[1] Commodity specialist, Division of Minerals.

A new and modern flotation plant was put into service in April near West Windsor, Vt., by the Eastern Magnesia Talc Co., Inc. Eventual annual production from this plant, of which a full description was published, is expected to be about 15,000 tons of special high-grade talc for cosmetic use in addition to about 35,000 tons of roofing-grade material.[2]

It was announced in July that Cyprus Mines Corp., holder of world-wide mining and shipping interests, as part of a diversification program had acquired all the outstanding stock of Sierra Talc Co., a major talc producer with over $4 million in annual sales from operation of mines and mills in 5 States.

TABLE 2.—Crude talc, soapstone, and pyrophyllite produced in the United States, by States

State	1963		1964	
	Short tons	Value (thousands)	Short tons	Value (thousands)
California	120,452	$1,427	132,601	$1,631
Georgia	42,000	93	40,400	135
Nevada	4,243	50	5,322	58
North Carolina	106,652	446	106,035	495
Texas	72,658	368	89,334	395
Virginia	3,696	9	3,775	9
Washington	2,969	18	2,680	18
Other States [1]	451,688	3,094	509,802	3,477
Total	804,358	5,505	889,949	6,218

[1] Includes Alabama, Arkansas, Maryland, Montana, New York, Pennsylvania, and Vermont.

TABLE 3.—Talc, soapstone, and pyrophyllite sold by producers in the United States, by classes

Year	Short tons	Value at shipping point		Short tons	Value at shipping point	
		Total	Average per ton		Total	Average per ton
	Crude			Sawed and manufactured		
1955-59 (average)	54,528	$326,992	$6.00	1,017	$435,117	$427.84
1960	44,477	240,077	5.40	860	410,194	476.97
1961	65,705	344,660	5.25	695	407,000	585.61
1962	58,699	302,841	5.16	660	416,000	630.30
1963	63,924	310,752	4.86	(1)	(1)	(1)
1964	73,438	370,851	5.05	(1)	(1)	(1)
	Ground [2]			Total		
1955-59 (average)	668,935	$14,425,172	$21.56	724,480	$15,187,281	$20.96
1960	676,344	15,423,193	22.80	721,681	16,073,464	22.27
1961	661,053	15,270,294	23.10	727,453	16,021,954	22.02
1962	717,559	17,162,912	23.92	776,918	17,881,753	23.02
1963	730,087	18,109,581	24.80	794,011	18,420,333	23.20
1964	801,587	18,602,527	23.21	875,025	18,973,378	21.68

(1) Included with "Ground" to avoid disclosing individual company confidential data.
[2] Includes some crushed material.

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[2] Pit and Quarry. V. 57, No. 6, December 1964, pp. 72-76, 101.

CONSUMPTION AND USES

Consumption of talc, soapstone, and pyrophyllite in the United States in 1964 was about 8 percent more than in 1963. The chief consuming industries were ceramics, 34 percent of the total; paint, 20 percent; and insecticides, 8 percent. A notable feature of the 1964 uses pattern was that the quantity used in paint was more than 21 percent greater than in 1963 and that the paint and ceramics industries both consumed talc in alltime record amounts.

TABLE 4.—Pyrophyllite[1] produced and sold by producers in the United States

Year	Production	Sales	
	Short tons	Short tons	Value
1955–59 (average)	158,681	155,422	$2,051,723
1960	124,631	132,357	1,849,656
1961	157,421	129,707	1,798,816
1962	125,247	133,336	1,779,075
1963	129,018	132,719	1,664,329
1964	136,108	142,532	1,843,283

[1] Includes sericite schist.

TABLE 5.—Talc, soapstone, and pyrophyllite sold or used by producers in the United States, by uses

(Short tons)

Use	Talc and soapstone		Pyrophyllite	
	1963	1964	1963	1964
Ceramics	236,893	249,246	34,294	32,631
Foundry facings	4,391	4,797	---	W
Insecticides	39,826	38,927	25,408	27,661
Paint	130,596	160,653	W	W
Paper	29,159	31,585	---	---
Rice polishing	1,847	W	---	---
Roofing	52,639	57,150	W	W
Rubber	31,032	32,352	W	W
Textile	8,341	7,057	---	---
Toilet preparations	10,504	16,739	---	---
Other	[1] 116,064	[1] 133,987	[2] 73,017	[2] 82,240
Total	661,292	732,493	132,719	142,532

W Withheld to avoid disclosing individual company confidential data.

[1] Includes uses indicated by symbol "W", adhesive, asphalt filler, composition floor and wall tile, crayons, exports, fertilizer, grease manufacture, insulated wire and cable, joint cement, patching compound, plastics, refractories, stucco, vault manufacturing, and miscellaneous products.

[2] Includes uses indicated by symbol "W", and asphalt filler, battery boxes, exports, joint cement, plaster products, refractories, stucco, and related products.

PRICES

The talc prices shown in trade journals and quoted from them in the 1963 Yearbook remained unchanged throughout 1964. Although those quotations are indicative of the general range of talc prices, actual selling prices, like those of many other nonmetallic mineral commodities, are negotiated and depend upon the amounts purchased and upon classification of the material according to a wide range of specifications.

FOREIGN TRADE

United States imports of talc declined substantially in 1964 chiefly because the quantity received from Italy was the least since 1957. That country, however, maintained its position as foremost source of imported talc and furnished 63 percent of the total, followed by France with 24 percent and Canada with 10 percent.

Exports of talc, soapstone, and pyrophyllite in 1964 were at the highest level in history, 24 percent more than in any previous year. Canada and Mexico were the principal recipients, taking 28,504 and 24,120 short tons, respectively, and lesser amounts, varying between

TABLE 6.—U.S. imports for consumption of talc, steatite or soapstone, and French chalk, by classes and countries

Year	Crude and unground		Ground, washed, powdered, or pulverized, except toilet preparations		Cut and sawed		Total unmanufactured	
	Short tons	Value	Short tons	Value	Short tons	Value	Short tons	Value
1955-59 (average)	210	$20,922	23,916	$757,828	87	$37,625	24,213	$816,375
1960	74	3,376	23,850	821,054	51	24,416	23,975	848,846
1961	40	4,859	[1] 27,238	[1] 1,012,358	84	37,527	27,362	1,054,744
1962	27	3,536	25,650	1,015,131	100	50,577	25,777	1,069,244
1963:								
Canada	-------	-------	2,100	39,055	-------	-------	2,100	39,055
France	-------	-------	4,932	108,302	-------	-------	4,932	108,302
India	16	2,250	632	18,469	-------	-------	648	20,719
Italy	929	45,465	16,737	797,182	228	14,073	17,894	856,720
Japan	-------	-------	-------	-------	105	62,919	105	62,919
Taiwan	-------	-------	-------	-------	2	504	2	504
Total	945	47,715	24,401	963,008	335	77,496	25,681	1,088,219
1964:								
Canada	35	490	2,327	46,400	-------	-------	2,362	46,890
France	-------	-------	5,396	122,751	1	254	5,397	123,005
India	6	700	499	16,726	-------	-------	505	17,426
Italy	330	14,402	14,039	669,336	2	810	14,371	684,548
Japan	-------	-------	-------	-------	74	44,320	74	44,320
Sweden	-------	-------	-------	-------	5	942	5	942
Total	371	15,592	22,261	855,213	82	46,326	22,714	917,131

[1] Data adjusted by Bureau of Mines to exclude less than 1 ton ($930) of ground, washed, powdered, or pulverized, valued not over $14 per ton from Hong Kong.

Source: Bureau of the Census.

TABLE 7.—U.S. exports of talc, pyrophyllite, and talcum powders

Year	Talc, steatite, soapstone, and pyrophyllite				Powders—talcum (in packages), face, and compact (value thousands)
	Crude and ground		Manufactures, n.e.c.[1]		
	Short tons	Value (thousands)	Short tons	Value (thousands)	
1955-59 (average)	46,989	$1,177	181	$116	$1,311
1960	59,457	1,801	158	92	1,378
1961	47,912	1,721	134	84	1,396
1962	46,939	2,133	122	97	1,286
1963	56,483	2,690	107	88	1,140
1964	73,998	3,316	128	75	1,068

[1] Not elsewhere classified.

Source: Bureau of the Census.

3,871 tons to Sweden and 4 tons to Thailand, were exported to 52 other countries. Production of talc for export was reported by five companies from operations in six States.

WORLD REVIEW

World production of talc, soapstone, and pyrophyllite, increasing in all but 4 of the years since World War II, has more than doubled since 1955 and attained in 1964 the highest level in history.

Canada.—Canada Talc Industries, Ltd., announced plans for financing a $300,000 expansion of its talc mining operation at Madoc, Ontario. Diamond drilling indicated the existence of about 20 million tons of open-pit ore in the magnesite-talc properties of Canadian Magnesite Mines near Timmins, Ontario, and test shipments of this material were sent to a pilot treatment plant west of North Bay.

New Zealand.—Opening was announced of talc-magnesite deposits in the Cobb River valley.

South Africa, Republic of.—Production of pyrophyllite (wonderstone) was 1,878 short tons in 1964, 8 percent less than in 1963. Almost 79 percent of the 1964 output was exported to the United States, and while the weight so disposed of was somewhat less than the corresponding quantity in 1963, there was a marked increase in the unit value that brought the total value 15 percent higher.

TABLE 8.—World production of talc, soapstone, and pyrophyllite by countries [1]

(Short tons)

Country [1]	1955-59 (average)	1960	1961	1962	1963	1964 [p]
North America:						
Canada (shipments)	33,158	41,636	48,116	46,161	54,250	57,150
Mexico	[3] 4,136	4,819	4,616	[e] 4,400	[e] 4,400	[e] 4,400
United States	731,785	734,473	762,380	771,728	804,358	889,949
Total	769,079	780,928	815,112	822,289	863,008	951,499
South America:						
Argentina	27,273	[4] 20,989	[4] 20,625	[4] 16,373	[4] 16,439	[4] 11,466
Brazil	27,141	21,956	26,209	42,218	38,487	[5] 38,487
Colombia	---	390	600	720	720	[e] 805
Peru	2,840	1,732	3,236	1,896	3,620	2,943
Uruguay	1,744	3,297	1,857	1,890	1,890	[5] 1,890
Total	58,998	48,364	52,527	63,097	61,156	55,591
Europe:						
Austria	73,236	90,695	93,639	83,523	72,360	79,225
Finland	7,659	11,008	6,967	7,088	7,447	6,600
France	156,836	206,997	245,427	206,000	174,298	225,000
Germany, West (marketable)	34,392	32,277	32,696	30,411	29,100	30,975
Greece	2,192	2,008	2,044	2,662	[e] 2,800	[e] 3,100
Italy	113,406	137,117	148,706	140,171	149,385	145,773
Norway	104,101	113,628	[e] 120,000	142,000	[e] 142,000	152,000
Portugal	69	750	794	359	595	870
Spain	31,018	30,853	30,498	30,562	30,317	[5] 30,317
Sweden	14,520	17,466	17,270	19,201	[6] 19,201	[6] 19,201
U.S.S.R [e]	175,000	300,000	330,000	340,000	385,000	385,000
United Kingdom	5,035	7,244	7,761	8,240	[e] 7,700	[e] 7,770
Yugoslavia	584	---	---	---	---	---
Total [e] [1]	720,000	950,000	1,035,000	1,010,000	1,020,000	1,085,000
Asia:						
China [e]	155,000	165,000	165,000	165,000	165,000	165,000
India	54,239	102,947	106,696	121,749	130,044	149,149
Japan	395,913	652,953	699,510	649,651	944,551	1,164,013
Korea:						
North [e]	[7] 2,200	4,400	16,500	22,000	22,000	22,000
South	15,412	24,889	50,330	51,235	70,772	99,272
Pakistan (soapstone)	1,459	3,774	1,361	1,235	2,061	2,801
Philippines	---	6	209	130	105	108
Taiwan	5,851	11,637	14,824	14,781	16,300	18,718
Total [e]	630,000	965,000	1,055,000	1,025,000	1,350,000	1,620,000
Africa:						
Southern Rhodesia	---	---	---	23	21	18
South Africa, Republic of	1,608	1,979	3,279	13,921	7,566	7,294
Swaziland	[3] 396	1,714	2,955	3,902	3,052	2,199
United Arab Republic (Egypt)	6,915	5,391	6,565	6,753	7,861	18,542
Total	8,919	9,084	12,799	24,599	18,500	28,053
Oceania: Australia	16,379	18,112	16,613	16,790	15,605	[e] 19,800
World total (estimate) [1] [2]	2,200,000	2,780,000	2,990,000	2,960,000	3,330,000	3,760,000

[e] Estimate. [p] Preliminary.

[1] Talc or pyrophylite is reported in Rumania, but data are not available; no estimates are included in the total.

[2] This table incorporates some revisions. Data do not add exactly to totals shown because of rounding where estimated figures are included in the detail.

[3] Average annual production 1957-59.

[4] Excludes pyrophyllite, data is not available.

[5] 1963 data.

[6] 1962 data.

[7] 1959 data only.

TABLE 9.—Austria, France and Italy: Exports of talc and soapstone by countries [1]

(Short tons)

Destination	Exporting countries					
	Austria		France		Italy	
	1963	1964	1963	1964	1963	1964
Algeria	----------	----------	2,723	4,215	----------	----------
Belgium-Luxembourg	3,441	5,677	5,301	5,305	[2] 586	NA
Denmark	351	345	210	202	----------	----------
Finland	----------	----------	224	271	----------	----------
France	1,949	1,829	----------	----------	[2] 5,570	[2] 3,958
Germany:						
East	4,132	3,491	----------	----------	----------	----------
West	27,527	30,750	12,563	13,359	5,854	6,330
Hungary	2,443	2,359	----------	----------	----------	----------
Israel	91	198	562	871	----------	----------
Italy	9,561	7,858	735	808	----------	----------
Ivory Coast	----------	----------	348	315	----------	----------
Morocco	----------	----------	1,497	1,109	----------	----------
Netherlands	1,738	2,354	1,670	2,027	[2] 471	[2] 513
Poland	810	940	----------	----------	----------	----------
Portugal	1	2	699	1,139	NA	NA
Rumania	209	183	----------	----------	----------	----------
Sweden	60	77	978	946	NA	NA
Switzerland	3,657	4,351	10,019	8,026	[2] 1,467	[2] 1,477
Tunisia	----------	----------	707	742	----------	----------
United Kingdom	603	463	9,611	9,987	7,210	7,361
United States	----------	----------	5,212	5,493	17,305	14,809
Yugoslavia	69	581	----------	----------	----------	----------
Other countries	258	46	1,642	1,709	13,536	13,693
Total	56,900	61,504	54,701	56,524	51,999	48,141

NA Not available.

[1] This table incorporates some revisions.

[2] From import detail of trade returns of the respective country.

TECHNOLOGY

Studies were completed indicating that use of tremolitic talc as an auxiliary flux in electrical porcelain, hotel china, and sanitary ware results in a lowering of the maturing temperature and a greater resistance of the glazed ware to crazing without narrowing the firing range or adversely affecting the workability of the bodies.[3]

Differential thermal analysis, chemical analysis, and X-ray diffraction methods were used to investigate the development of high-temperature phases in the raw materials, both separately and in various mixtures, that are commonly used in high-talc ceramic bodies. The information thus obtained was used to define the solid-state reactions occurring in the firing process and to correlate some ceramic properties with the fired compositions of such bodies.[4] In similar research on 11

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[3] Emrich, Emerson W., and Richard C. Hannon. Talc as an Auxiliary Flux in Plastically Formed Ceramics. Am. Ceram. Soc. Bull., v. 43, No. 3, March 1964, pp. 186–190 .

[4] Planz, Egon. Solid-State Reactions in High-Talc Bodies. Am. Ceram. Soc. Bull., v. 43, No. 6, June 1964, pp. 443–447.

California talcs, a scheme was developed for quantitative calculation of the proportions of the various minerals that were present before and after firing.[5]

Pulverized talc is incorporated with a Teflon-metal base to produce a patented composition for bearings that require no lubrication.[6]

A process was patented for pretreatment by an electrical discharge in a gas-filled vessel to make talc ore more amenable to an electrostatic separation and concentration operation,[7] and three patents were granted on apparatus and methods for defiberizing or delaminating fibrous or laminar materials including talc.[8]

Other U.S. patents were issued on use of talc in a mastic coating composition,[9] as a coating and glossing agent for high-quality papers,[10] and in ditch and canal linings.[11]

Recent patents were granted on the use of pyrophyllite, calcined and mixed with water, glass, and sodium carbonate, to produce unburned refractories;[12] with siliceous clays for semisilica refractories;[13] and as a carrier in wettable herbicidal dusts.[14]

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[5] Haystek, Hendrik, and Egon Planz. Mineralogy and Ceramic Properties of Some California Talcs-Am. Ceram. Soc. Bull., v. 43, No. 8, August 1964, pp. 555–561.

[6] Rulon-Miller, R., and S. Ricklin (assigned to Dixon Corp., Bristol, Rhode Island). Bearing Composition. U.S. Pat 3,122,505, Feb. 25, 1964.

[7] Fraas, F. (assigned to U.S. Secretary of the Interior). Pretreatment of Minerals for Electrostatic Separa tion. U.S. Pat. 3,137,648, June 16, 1964.

[8] Cohn, M. I., and R. D. Perdue (assigned to Mineral Industries Corp. of America, Needham, Mass.). Method for Delaminating Sized Laminar Mineral Particles. U.S. Pat. 3,162,379, Dec. 22, 1964: Method of Treating Asbestos Minerals. U.S. Pat. 3,162,380, Dec. 22, 1964; and Apparatus for Delaminating Laminar Materials. U.S. Pat. 3,162,381, Dec. 22, 1964.

[9] Rolland, Grey F. (assigned to Benjamin Foster Co., Philadelphia, Pa.). Mastic Coating Composition. U.S. Pat. 3,147,266, Sept. 1, 1964.

[10] Exchaquet, L. (assigned to Stephen J. Wilson, Los Angeles, Calif.). Process for Preserving Materials. U.S. Pat. 3,152,003, Oct. 6, 1964.

[11] Cash, C. G., A. J. Hoiberg, and W. L. Butterfield (assigned to The Flintkote Co., New York, N.Y.). Material for Lining Canals and Ditches. U.S. Pat. 3,160,512, Dec. 8, 1964.

[12] Nameishi, N. (assigned to Harima Refractories Co., Ltd., Tokasago, Japan). Method for the Manufacture of Unburned Refractory Body. U.S. Pat. 3,132,955, May 12, 1964.

[13] Wilson, B. E., R. E. Birch, and D. F. Stock (assigned to Harbison-Walker Refractories Co., Pittsburgh, Pa.). Refractory Brick. U.S. Pat. 3,146,115, Aug. 25, 1964.

[14] Willard, J. R., and K. P. Dorschner (assigned to FMC Corp.). British Pat. 969,052, Sept. 9, 1964.

Thorium

By Charles T. Baroch[1]

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THE DOMESTIC thorium industry showed little change in 1964 from that of 1963. World production dropped for the second year, largely because of the closing in mid-1963 of the unique Steenkampskraal monazite mine in Cape Province, Republic of South Africa. Imports of monazite reflected the change and were only about one-third of 1963 imports. Part of apparent domestic consumption was made up by using company stocks.

LEGISLATION AND GOVERNMENT PROGRAMS

The Office of Emergency Planning on March 13, 1964, established a stockpile objective of 500,000 pounds of contained thorium oxide. Prior to this edict, thorium was not on the official list of stockpiled strategic and critical materials. However, as of December 31, 1964, the Defense Production Administration had 848,354 pounds of thorium oxide in processing residues, and the Commodity Credit Corporation stockpile contained 3,965,461 pounds of thorium oxide in the form of thorium nitrate.

On August 26, 1964, President Johnson signed Public Law 88–489, an act amending the Atomic Energy Act of 1954 to permit private ownership of special nuclear materials. The new law provided for a transition period for the changeover from Government to private ownership of nuclear-power reactor fuels, which became permissive upon enactment and becomes mandatory after June 30, 1973. Through December 31, 1970, the Atomic Energy Commission (AEC) must guarantee purchase prices for a period not to exceed 10 years for uranium enriched in the isotope 233, which is produced by neutron irradiation of thorium in breeder reactors. Nothing in the new law diminished existing authority of AEC in its regulatory and licensing activities.

DOMESTIC PRODUCTION

Mine Production.—Titanium Alloy Manufacturing Division, National Lead Co., produced a small quantity of byproduct monazite from Florida beach sands mined primarily for ilmenite. Production was slightly less than in 1963, but shipments were about 40 percent higher than in 1963 as the result of shipments from stocks.

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[1] Commodity specialist, Division of Minerals.

No production was reported from the thorite deposits in the Northwest. The Dow Chemical Co., which also had a 50-percent interest in the Elliot Lake, Canada, operations of Rio Tinto Dow, Ltd., reportedly leased a number of claims in Lemhi County, Idaho.

Refinery Production.—The principal domestic processors of thorium-bearing concentrates were American Potash & Chemical Corp., West Chicago, Ill.; Nuclear Fuel Services, Inc., Erwin, Tenn.; and Vitro Chemical Co., Chattanooga, Tenn. Firms engaged in the production of thorium metal, alloys, oxide pellets, or powder were The Babcock & Wilcox Co., Lynchburg, Va.; General Atomic Division, General Dynamics Corp., San Diego, Calif.; Kerr-McGee Oil Industries, Inc., Oklahoma City, Okla.; Metal Hydrides, Inc., Beverly, Mass.; Metals & Controls, Inc., Division of Texas Instruments, Attleboro, Mass.; National Lead Co., Albany, N.Y.; Nuclear Materials & Equipment Corp., Apollo, Pa.; United Nuclear Corp., Centreville, Md.; and Zirconium Corporation of America, Solon, Ohio.

Chief producer of magnesium-thorium alloys (magnesium hardener) was The Dow Chemical Co., Midland and Madison, Mich. Dominion Magnesium Ltd., Haley, Ontario, Canada, produced sintered pellets of pure thorium, thorium powder, and a thorium-magnesium master alloy containing about 40 percent thorium; the raw material was thorium concentrates recovered by Rio Tinto Dow Ltd. as a byproduct from the processing of Elliot Lake, Ontario, uranium ore. Another source of imported magnesium hardener alloy was Magnesium Elektron, Inc., New York, a subsidiary of Magnesium Elektron Ltd. of London.

The Babcock & Wilcox Co. completed a $3.5 million development laboratory at Lynchburg, Va., to be used in an attempt to make the thorium-uranium fuel cycle economic and bring it into commercial use. Nuclear Fuel Services, Inc., was formed early in 1964 by W. R. Grace & Co. and American Machine & Foundry Co. Nuclear Fuel's plant at Erwin, Tenn., produced more than 50 different uranium and thorium products, and a new plant was being built near West Valley, N.Y., to be used for processing spent nuclear fuels. Allis-Chalmers Manufacturing Co. continued its program with Comitato Nazionale per l'Energia Nucleari, which included designing the uranium 233 processing and fabrication facilities in Italy to be used for demonstrating the economics of the thorium-uranium fuel cycle for nuclear-power reactors.

CONSUMPTION AND USES

Nonenergy Uses.—Apparent consumption of thorium, reported by shipments of compounds, totaled about 50 tons of equivalent ThO_2, the same as in 1963. Major uses were in alloys, closely followed by use in thoriated gas mantles. Considerably smaller quantities were used in chemical processing, refractories, and electrical equipment. Magnesium alloys containing 3 percent thorium retain their strength at temperatures up to 600° F, and use of these alloys increased in 1964.

Energy Uses.—Thorium was used in thorium-uranium reactors where neutron irradiation produced fissionable U^{233}. AEC continued its thorium utilization program centered largely at Oak Ridge National Laboratory, Tenn., where a 9-month production program to produce

1,100 fuel elements containing 3 percent uranium 233 and 97 percent thorium oxides was completed. These elements were fabricated for use in critical experiments at Brookhaven National Laboratory, and the project was the first engineering-scale demonstration of semi-remote fabrication of such elements. AEC also granted a contract of $385,000 to The Babcock & Wilcox Co. for the first year of a 3-year study to produce low-cost thorium-based reactor fuel.

Powerplant prototype reactors using thorium that were in operation or in an advanced stage of construction were the Elk River, Minn., 23 megawatt (Mw) station of AEC and Rural Cooperative Power Association and the Peach Bottom Atomic Power Station of Philadelphia Electric Co. with a 40-Mw high-temperature gas-cooled reactor, which was scheduled for operation early in 1965. The Indian Point (N.Y.) reactor of Consolidated Edison Co. was shut down from January 30 to June 25, 1964, for a required inspection of the uranium oxide-thorium oxide fuel elements and some minor repairs. Full power was resumed in mid-August.

Fourteen utilities serving the Ohio River Valley area, called East Central Nuclear Group, joined with The Babcock & Wilcox Co. in a program to develop a low-cost breeder reactor. AEC accepted proposals as bases for negotiating memoranda of understanding of cooperative arrangements for two prototype advanced converter reactor plants. One was proposed by Rochester (N.Y.) Gas and Electric Corp., and the other was proposed by the Department of Water Resources of California; both were based on breeder-reactor concepts. The California proposal would start with a 525-Mw seed-blanket reactor employing the thorium fuel cycle and, if situated on the coast, it might include a sea water desalting facility. AEC also stated its intent to support research and development work by The Babcock & Wilcox Co. on the thorium fuel cycle for the spectral shift reactor and by Atomics International Division of North American Aviation, Inc. on the sodium-graphite reactor.

PRICES

Monazite quotations listed in E&MJ Metal and Mineral Markets have been unchanged since 1960. Prices per pound c.i.f. U.S. ports were as follows: Massive, 55 percent rare-earth oxides including thoria were 14 cents; sands ranged from 10 to 15 cents; 66 percent sand was 18 cents; 68 percent sand was 20 cents.

Domestic thorium oxide was offered at $7 per pound in lots of 10 to 49 pounds, and the high-density grade, suitable for use in reactors, was priced from $7 per pound in large quantities to about $12 per pound in small quantities. Thorium nitrate, purified and in fiber drums, 100-pound lots or more was quoted at $3.50 per pound, f.o.b. works; other grades ranged from $3.50 to $7.65 per pound, and mantle-grade ranged from $2.65 to $3.15 per pound. Thorium metal powder or pellets ranged from $15 to $50 per pound. The ranges in prices depended on the form, quality, and quantity purchased.

Canadian metallurgical-grade thorium oxide remained at the U.S. equivalent of $4.63 per pound, and metallurgical-grade thorium fluoride was $3.93 per pound.

FOREIGN TRADE

Imports of thorium ore (monazite) as reported by Bureau of the Census in 1964 consisted of 1,450 short tons from Australia, 335 tons from Ceylon, and 320 tons from Malaysia, a total of 2,105 tons valued at $186,458. This was 32.7 percent of the quantity received in 1963, and it was the first time in many years that no imports were received from the Republic of South Africa. This was the result of the closing for an indefinite period of the Steenkampskraal monazite mine in Cape Province. Other imports of thorium materials included 2,900 pounds of thorium metal from Canada valued at $28,918 and 95 pounds of thorium compounds and salts valued at $10,082, principally from West Germany. Thorium alloys are combined by the Bureau of the Census into class 632.6800, "alloys of barium, boron, calcium, strontium, thorium, or vanadium"; hence, quantity and value of thorium alloys cannot be designated separately. The value of the entire group for 1964 was $1.6 million.

Imports of thoriated gas mantles have been rising over the past few years. These come principally from the United Kingdom, with a much smaller quantity from Austria, and still less from Hong Kong, West Germany, and France. Roughly, 1 pound of ThO_2 will produce about 1,000 mantles.

TABLE 1.—Imports of thoriated gas mantles

Year	Number thousands	Value
1961	1,070	$117,344
1962	1,858	179,787
1963	1,934	186,049
1964	2,218	194,063

Exports of thorium ores, concentrates, and compounds aggregated 71,929 pounds valued at $352,568; 80 percent of the volume and 73 percent of the value went in order to the Philippines, Hong Kong, United Kingdom, and West Germany, with the balance going in small lots to 13 other countries. Exports of thorium metal and thorium-bearing alloys, except special nuclear material, totaled 587 pounds valued at $36,680 and went to 10 countries.

WORLD REVIEW

India.—The monazite in Indian beach sands is recovered, along with ilmenite and zircon, by simple gravity methods. Most of it came from Manavalakurichi in Madras, and some came from Quilon in Kerala. It was processed in the plant of Indian Rare Earths Ltd. at Alwaye which is owned jointly by the Indian Government and the Government of Kerala. Thorium hydroxide and rare-earth compounds are recovered by chemical treatment. The annual report of Indian Rare Earths Ltd. stated that 2,933 tons of monazite were processed in their fiscal year ending March 31, 1963, compared with 1,797 tons in the previous year. Reduction in sales and accumulation of thorium hydroxide stocks indicated that production would be restricted in the 1964 fiscal year.[2]

India's Department of Atomic Energy celebrated the 10th anniversary of its establishment on August 3, 1964. The Atomic Energy Establishment at Trombay is a large nuclear-research center actively operating three test reactors, plutonium and uranium plants, and associated radiochemistry laboratories and shops. Other centers of activity include research centers at Thumba and Bombay (Tata Institute), a uranium mill at Jaduguda, and nuclear power stations at Tarapur, near Bombay, and Rana Pratap Sagar in Rajasthan. Among its research projects were plans for building an experimental heavy-water moderated reactor with plutonium and thorium as fuel. This would help develop the technology of using plutonium in reactors, one of the means essential for producing fissionable U^{233} from nonfissionable Th^{232}. This is of special interest to India because of its large reserve of high-thorium (9 percent) monazite.

Malagasy Republic.—Both monazite and uranothorianite continued to be mined, and the concentrates were shipped to the Commissariat à l'Énergie Atomique (French Atomic Energy Commission). Monazite has been mined for many years by Société d'Exploitation des Monazites from beach sands at Fort Dauphin, continually worked over by wave action. However, the reserve is nearing depletion and the plant was being moved to a deposit at Vohibarika, about 60 miles north of Fort Dauphin. Other sand dune deposits at Antete, 25 miles southwest of Fort Dauphin, continued to be mined.[3]

WORLD RESERVES

Many new reserve data were presented at the Third United Nations International Conference on the Peaceful Uses of Atomic Energy held in Geneva in May 1964.

The known world reserve in high-grade deposits and easily mined placer deposits was estimated at about 740,000 tons. Additional thorium occurrences are known, and other deposits no doubt will be found in new districts and at depth in known districts. Thus, the potential domestic resources in vein deposits in known areas of low cost ThO_2 (under $10 per pound) were estimated to be 500,000 tons, with another 300,000 tons estimated to be available in low to moderately high-cost placer deposits, dependent on byproducts in part. All known and potential resources in known areas above a grade of 300 parts per million (ppm) ThO_2, including the placer deposits noted above, would aggregate 1.4 million tons of ThO_2. Estimated known and potential resources in igneous and metamorphic rock containing between 30 and 300 ppm, would add over 75 million tons of ThO_2 to the total.[4]

In addition to a 30,000-ton reserve in Brazil, an estimated 130,000 tons of thorium is believed to be present in the low-grade (0.07 percent ThO_2) pyrochlore carbonatite at Araxa in Minas Gerais. This thorium might be recoverable as a byproduct of columbium.

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[2] Bureau of Mines. Mineral Trade Notes. V. 60, No. 1, January 1965, pp. 49–51.

[3] Bureau of Mines. Mineral Trade Notes. V. 58, No. 4, April 1964, pp. 39–40.

[4] Olson, J. C., and W. C. Overstreet. Geologic Distribution and Resources of Thorium. U.S. Geol. Survey Bull. 1204, 1964, 61 pp.

TABLE 2.—World resources of thorium

Country	Thousand tons ThO_2 equivalent	Principal type of deposits
India, Ceylon, Nepal, Pakistan, Afghanistan	250	Placer.
Canada	200	Sedimentary, igneous, and metamorphic rocks.
United States	100	Vein, placer.
U.S.S.R. and Eastern Europe	100	
Brazil	30	Placer, igneous, and metamorphic rocks.
Western Africa	15	Do.
Australia	10	Do.
Egypt	10	Placer.
Malagasy Republic	10	Placer, igneous, and metamorphic rocks.
Malawi	10	Placer.
South Africa, Republic of	10	Vein.

Source: U.S. Geological Survey Bulletin 1204.

The Canadian thorium resources are mainly in the conglomeritic uranium ore at Elliot Lake, Ontario, with most of the balance contained in uranium deposits at Beaverlodge Lake, Saskatchewan. The present and potential resources, plus geologically prognosticated resources presumed to be available as a byproduct of uranium at a price of under $20 per pound of U_3O_8, were estimated to be about 700,000 tons of ThO_2.[5]

TECHNOLOGY

The Highlandcroft, Oliverian, and New Hampshire Plutonic Series of rock formations, all mainly in New Hampshire, were studied and their thorium and uranium contents determined. Thorium content ranged from 2.8 to 57 parts per million and uranium content ranged from 0.6 to 15.9 parts per million.[6]

The very rich ilmenite beach sands of Chavara, India, contain over 90 percent ilmenite, rutile, and zircon, and carry about 0.5 percent monazite, the balance being mainly sillimanite and quartz, with a little garnet and other minerals. The sands are passed through 30-mesh screens to remove seashells and other debris, and about 60 percent of the magnetic ilmenite is first removed in low-intensity cross-belt magnetic separators. The residue is subjected to high-intensity magnetic separators of the induced roll type, producing a product rich in monazite. This fraction is again treated in low-intensity machines to recover additional ilmenite free from monazite. Monazite, rutile, and zircon concentrates are finally cleaned after drying by high-tension electrostatic separators. The grade of monazite obtained was 95.6 percent with a recovery of 82.7 percent. Monazite from this locality contains about 9 percent ThO_2, compared with about 6 percent and 5 percent, respectively, for Brazilian and Australian monazites.[7]

Thorium and yttrium oxides were recovered separately from siliceous ores of the Powderhorn, Colo., area on a laboratory scale. The ore, containing 1.2 percent ThO_2, 0.5 percent Y_2O_3, and about 0.4 percent lanthanons, was baked in a special manner with 36-percent sulfuric acid, leached, and washed. The pregnant thorium-yttrium sulfate leach solution was fed to a solvent-extraction system using a primary alkylamine and isodecyl alcohol in kerosine to remove the thorium, while the aqueous raffinate passed on to yttrium recovery. The thorium was stripped from the organic phase into an ammonium carbonate solution. Steam distillation removed the ammonium carbonate from the new solution, which precipitated hydrated thorium oxide. The yttrium, after removing iron from the solution, was recovered by solvent extraction with di-2-ethylhexyl phosphoric acid in kerosine. Recoveries were about 95 percent of the thorium as 99 percent ThO_2, and 95 percent of the yttrium as 77 percent Y_2O_3.[8]

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[5] Griffith, J. W., and S. M. Roscoe. Canadian Resources of Uranium and Thorium. Dept. Mines and Tech. Surveys, Min. Res. Div. (Ottawa, Canada). Miner. Inf. Bull. MR 77, 1964, 12 pp.

[6] Lyons, John B. Distribution of Thorium and Uranium in Three Early Paleozoic Plutonic Series of New Hampshire. U.S. Geol. Survey Bull. 1144–F, 1964, 43 pp.

[7] Rao, Y. V. N., G. V. U. Rao, and K. K. Majumdar. Recovery of Economic Minerals From India Beach Sands. Min. Magazine (London), v. 110, No. 6, June 1964, pp. 401–409.

Direct precipitation on a laboratory scale of thorium sulfate as $Th(SO_4)_2.9H_2O$ from an organic solvent proved to be an effective means of purifying thorium. Thorium nitrate dissolved in a solvent consisting of 46 percent tributyl-phosphate (TBP) in a paraffinic naphtha was treated in a turbine mixer with 4-normal sulfuric acid-solution, precipitating crystalline thorium sulfate relatively free of contaminating elements, which settled out in the aqueous phase. The separation of thorium from uranium was especially good.[9]

A method of preparing high-purity thorium metal by sodium reduction of thorium tetrachloride was developed and tested in quantities up to 20 kilograms per batch. Commercial grade thorium nitrate or oxalate hydrates were decomposed thermally to ThO_2, which was formed into ¼- to 1-inch diameter nodules and chlorinated at 550° C with carbon tetrachloride or phosgene. The thorium tetrachloride was purified by distillation in a two-zone vacuum furnace to remove nonvolatile impurities, which were mainly oxides of thorium. The pure thorium tetrachloride was reduced at a temperature above 300° C with sodium under an argon atmosphere in a special externally heated vertical tube furnace. Byproduct salts and excess sodium reductant were removed from the thorium sponge by vacuum distillation at about 1,000° C.[10]

The relatively new dispersion-strengthened alloy known as TD Nickel, containing about 2 percent ThO_2 dispersed in nickel, was examined by transmission electron microscopy in the extruded, annealed, and deformed states. Important conclusions of the study inferred that the thoria particles act as strong barriers to dislocation motion during both deformation (slip) and annealing, while during deformation, the dislocations tangle around the thoria particles and a cell structure is developed. Also the thoria particles inhibit crystallization and twin growth so that some strengthening may arise from the high density of small annealing twins.[11] Alloy systems of thorium with osmium, iridium, platinum, and palladium were studied for the full range of compositions in the temperature range 1,000° to 1,500° C, and phase diagrams were developed from the data.[12]

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[8] Borrowman, S. R., and D. W. Bridges. Solvent Extraction Recovery of Thorium and Yttrium From Siliceous Colorado Ores. BuMines Rept. of Inv. 6457, 1964, 16 pp.

[9] Bril, K. J., and P. G. de Sabóia Arújo. Decontamination of Thorium. Process in Design Eng.: Ind. and Eng. Chem., v. 3, No. 1, January 1964, pp. 8–10.

[10] Poppleton, H. O., and F. E. Block. A Process for the Preparation of Thorium by Sodium Reduction of Thorium Tetrachloride. BuMines Rept. of Inv. 6227, 1964, 20 pp.

[11] von Heimendahl, M., and G. Thomas. Substructure and Mechanical Properties of TD–Nickel. Trans. AIME. v. 230 (Met. Soc.), 1964, pp. 1520–1528.

The Babcock & Wilcox Co., which claims it has invested over $45 million of its own money in nuclear research, development, and manufacturing developments, completed a new $3.5-million laboratory at Lynchburg, Va., which includes a powerful test reactor. Work will center on ways to reduce fuel costs. AEC as part of its thorium utilization program authorized $385,000 for a 1-year program at the new laboratory to study the physical properties of a low-cost thorium fuel system.[13]

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[12] Thomson, J. R. Alloys of Thorium With Certain Transition Metals. J. Less-Common Metals (Amsterdam, Netherlands), pt. II, v. 6, No. 1, January 1964, pp. 3–10; pt. III, v. 6, No. 2, February 1964, pp. 94–99.

[13] Nucleonics. B. & W. Completes Development Lab for Thorium Fuels. V. 22, No. 3, March 1964, p. 84; Tasks for B. & W. V. 22, No. 9, September 1964, p. 26.

Tin

By John E. Shelton [1]

◆

PRICES for tin rose to alltime highs in all world markets during 1964. In New York, the price for prompt tin reached 217 cents per pound and in London, a high of £1,715 per long ton (214.375 cents per pound) for spot tin was recorded. The annual average price for Straits tin in New York was more than 41 cents per pound higher than in 1963.

In the United States, consumption of primary tin increased 6 percent. The use of secondary tin rose 5 percent, reversing a 4-year downward trend.

Free world consumption continued to exceed free world production, and sales of surplus tin from the U.S. national stockpile helped to fill the deficit.

The United States was again the leading free world consumer of tin, followed by the United Kingdom and Japan.

TABLE 1.—Salient tin statistics

(Long tons)

	1955-59 (average)	1960	1961	1962	1963	1964
United States:						
Production:						
Mine	30	10	W	W	W	W
Smelter	[1] 11,547	W	W	W	W	W
Secondary	25,710	22,050	21,690	21,040	22,332	23,508
Imports for consumption:						
Metal	53,658	39,538	39,893	41,401	43,283	31,582
Ore (tin content)	10,621	14,026	8,917	5,364	1,650	5,190
Exports (exports and reexports)	1,248	857	800	435	1,625	4,041
Consumption:						
Primary	53,712	51,530	50,288	54,602	55,209	58,476
Secondary	28,943	29,030	27,962	24,483	23,094	24,304
Price: Straits tin, New York, average cents per pound	97.85	101.40	113.27	114.61	116.64	157.72
World:						
Production:						
Mine	182,400	180,400	184,100	186,600	190,400	194,200
Smelter	181,300	189,200	184,000	189,500	192,000	189,300

W Withheld to avoid disclosing individual company confidential data.
[1] Includes tin content of alloys made directly from ores.

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[1] Commodity specialist, Division of Minerals.

LEGISLATION AND GOVERNMENT PROGRAMS

The U.S. General Services Administration (GSA) continued to dispose of pig tin declared excess to the national stockpile needs. At the beginning of 1964, GSA offered for sale a maximum of 600 long tons weekly. On February 20, the limitation was removed, and by February 28 the 9,000 tons allocated for the period October 1, 1963, to March 31, 1964, was sold. Of an additional 5,000 tons made available, 2,955 was sold by March 20, when a long-range disposal plan was announced. The first 1-year program anticipated the sale of about 20,000 tons. About 14,000 tons was sold by September 20, and GSA made available a total of 18,000 tons from September 20, 1964, to March 19, 1965. Of the total sales of 31,147 tons of tin by GSA in 1964, 28,994 tons went to industry, 2,140 tons went to the Agency for International Development, and 13 tons went to other Government agencies.

On December 31, there was 308,741 tons of tin in the Government stockpiles; of this, 301,236 tons was in the national (strategic) stockpile, and 7,505 tons, obtained largely through the Commodity Credit Corporation barter program, was in the supplemental stockpile.

The Export Control Act of 1959, extended to June 30, 1965, governed the destination of tin shipments. Exports were under general license except to China, Cuba, North Korea, North Viet-Nam, and the Pacific region of the U.S.S.R. Regulations administered by the Office of Export Control, U.S. Department of Commerce, required a license (except to Canada) for exports of detinned tinplate, terneplate scrap, and detinned cans. Exports of tinplate, terneplate scrap, and old cans were exempt from licensing except to the Sino-Soviet bloc, Hong Kong, and Macao.

The foreign assets control regulations of the U.S. Treasury Department prohibited the entry of Chinese tin. Soviet tin could enter the United States but required a license (none was issued) on the presumption that it might be of Chinese origin. Alloys that might include Chinese and/or Soviet tin were prohibited.

The Office of Minerals Exploration offered financial assistance to the extent of 50 percent of the total allowable costs for exploration of eligible domestic tin deposits.

GSA administered the production payment provisions of the Texas City, Tex., tin smelter sales contract.

DOMESTIC PRODUCTION

MINE PRODUCTION

Small quantities of tin ore were produced in Alaska and California. Some tin concentrate was recovered as a byproduct of molybdenum mining in Colorado.

SMELTER PRODUCTION

Tin smelting was continued by Wah Chang Corp., Texas City, Tex. The production payment provisions of the sales contract were administered by GSA. Under this program, GSA received $24,419 as payment on smelter production of 3,958 long tons of tin produced during the year. On February 15, GSA held a note with a balance of $630,000 bearing interest at 4 percent per year, obtained from the sale of the tin smelter.

SECONDARY TIN

Production of secondary tin increased 5 percent. About 81 percent was recovered from seven scrap items—drosses, composition or red brass, tinplate, bronze, railroad-car boxes, auto radiators, and solder. Tin recovered from old scrap increased 9 percent. New scrap supplied 85 tons more than in 1963. The largest tonnage of tin was recovered in bronze and brass, which decreased 1 percent. Next in rank was tin reclaimed in solder.

The tonnage of tinplate scrap treated in 1964 increased 14 percent, reversing a 17-year downward trend.

TABLE 2.—Stocks, receipts, and consumption of new and old scrap and tin recovered in the United States in 1964

(Long tons)

Type of scrap and class of consumer	Gross weight of scrap						Tin recovered		
	Stocks Jan. 1	Receipts	Consumption			Stocks Dec. 31			
			New	Old	Total		New	Old	Total
Copper-base scrap:									
Secondary smelters:									
Auto radiators (unsweated)	[r] 3,171	49,439	------	48,080	48,080	4,530	------	2,068	2,068
Brass, composition or red	4,638	82,669	22,118	61,044	83,162	4,145	972	2,295	3,267
Brass, low (silicon bronze)	[r] 315	2,753	1,811	977	2,788	280	------	4	4
Brass, yellow	5,134	56,223	8,305	47,280	55,585	5,772	26	432	458
Bronze	1,577	28,259	7,522	20,728	28,250	1,586	592	1,632	2,224
Low-grade scrap and residues	3,942	37,402	27,517	8,868	36,385	4,959	22	------	22
Nickel silver	647	3,740	328	3,311	3,639	748	3	24	27
Railroad-car boxes	[r] 201	618	------	748	748	71	------	35	35
Total	[r] 19,625	261,103	67,601	191,036	258,637	22,091	1,615	6,490	8,105
Brass mills: [1]									
Brass, low (silicon bronze)	3,913	24,310	24,310	------	24,310	2,299	------	------	------
Brass, yellow	16,305	202,345	202,345	------	202,345	9,757	103	------	103
Bronze	1,006	3,074	3,074	------	3,074	745	148	------	148
Mixed alloy scrap	12,886	12,489	12,489	------	12,489	9,594	47	------	47
Nickel silver	2,940	8,398	8,398	------	8,398	3,729	------	------	------
Total	37,050	250,616	250,616	------	250,616	26,124	298	------	298
Foundries and other plants: [2]									
Auto radiators (unsweated)	1,189	9,224	------	7,956	7,956	2,457	------	358	358
Brass, composition or red	1,364	3,369	1,376	2,659	4,035	698	65	126	191
Brass, low (silicon bronze)	402	436	158	513	671	167	------	------	------
Brass, yellow	1,483	7,824	3,551	4,705	8,256	1,051	4	42	46
Bronze	1,197	1,385	702	1,134	1,836	746	54	87	141
Low-grade scrap and residues	1,934	8,955	1,854	7,709	9,563	1,326	------	------	------
Nickel silver	18	36	1	50	51	3	------	1	1
Railroad-car boxes	1,920	37,047	------	37,182	37,182	1,785	------	1,766	1,766
Total	9,507	68,276	7,642	61,908	69,550	8,233	123	2,380	2,503
Total tin from copper-base scrap	------	------	------	------	------	------	2,036	8,870	10,906
Lead-base scrap:									
Smelters, refiners and others:									
Babbitt	[r] 444	15,054	------	15,173	15,173	325	------	736	736
Battery lead plates	[r] 31,490	409,439	------	406,726	406,726	34,203	------	427	427
Drosses and residues	20,254	83,166	81,556	------	81,556	21,864	1,703	------	1,703
Solder and tinny lead	[r] 359	9,905	------	9,961	9,961	303	------	1,739	1,739
Type metals	1,417	22,590	------	23,002	23,002	1,005	------	1,093	1,093
Total	[r] 53,964	540,154	81,556	454,862	536,418	57,700	1,703	3,995	5,698
Tin-base scrap:									
Smelters, refiners, and others:									
Babbitt	42	469	5	471	476	35	5	394	399
Block-tin pipe	[r] 19	441	------	447	447	13	------	443	443
Drosses and residues	[r] 669	3,993	4,174	------	4,174	488	2,619	------	2,619
Pewter	5	41	------	45	45	1	------	38	38
Total	735	4,944	4,179	963	5,142	537	2,624	875	3,499
Tinplate scrap: Detinning plants	------	------	761,178	------	761,178	------	3,405	------	3,405
Total tin recovered	------	------	------	------	------	------	9,768	13,740	23,508

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[r] Revised.

[1] Lines in brass mills and total sections do not balance as stocks include home scrap and purchased scrap assumed to equal receipts.

[2] Omits "machine shop scrap."

TABLE 3.—Secondary tin recovered from scrap processed at detinning plants in the United States

	1963	1964
Tinplate scrap treated [1] ..... long tons	673,323	761,178
Tin recovered in the form of—		
Metal ..... do	2,342	2,774
Compounds (tin content) ..... do	589	455
Total [2] ..... do	2,931	3,229
Weight of tin compounds produced ..... do	1,168	1,191
Average quantity of tin recovered per long ton of tinplate scrap used ..... pounds	9.75	10.02
Average delivered cost of tinplate scrap ..... per long ton	$21.48	$31.26

[1] Tinplate clippings and old tin-coated containers have been combined to avoid disclosing individual company confidential data.

[2] Recovery from tinplate scrap treated only. In addition, detinners recovered 455 long tons (405 tons in 1963) of tin as metal and in compounds from tin-base scrap and residues in 1964.

TABLE 4.—Tin recovered from scrap processed in the United States, by form of recovery

(Long tons)

Form of recovery	1963	1964	Form of recovery	1963	1964
Tin metal:			Solder	4,845	5,525
At detinning plants	2,693	2,992	Type metal	1,496	1,527
At other plants	368	342	Babbitt	1,105	1,079
			Antimonial lead	315	328
Total	3,061	3,334	Chemical compounds	717	969
			Miscellaneous [1]	99	106
Bronze and brass:					
From copper-base scrap	10,243	10,218	Total	8,577	9,534
From lead-base and tin-base scrap	451	422	Grand total	22,332	23,508
			Value ..... thousands	$58,350	$83,050
Total	10,694	10,640			

[1] Includes foil, cable lead, and terne metal.

CONSUMPTION

Total tin consumption in the United States increased 4,477 long tons in 1964. The use of primary tin rose 3,267 tons, and use of secondary tin increased 1,210 tons. Almost 82 percent of the tin was used in three items—tinplate, solder, and bronze and brass. Consumption of tin in tinplate increased 10 percent and accounted for 53 percent of the total primary tin.

Tinplate production was 12-percent greater than in 1963. Electrolytic tinplate comprised 97 percent (96 percent in 1963), and hot-dipped tinplate comprised 3 percent of the total output. The United States accounted for about 43 percent of the world's total use of tin for tinplate. About 90 percent of the U.S. production of tinplate was used for making cans, of which 64 percent was for food pack and 36 percent for nonfood products. The tonnage of tinplate shipments to canmakers increased 5 percent. Shipments of cans increased 6 percent for packing food and 5 percent for nonfood products. Beer ranked first among products packed, and the production of beer cans rose 11 percent. Cans for vegetables and vegetable juice, in second place, increased 1 percent, and cans for fruit and fruit juice increased 9 percent. Cans for soft drinks increased for the eighth consecutive year. Cans for coffee, meat, pet foods, and pressure packing increased, while the use of cans for fish and oil decreased.

TABLE 5.—Consumption of primary and secondary tin in the United States

(Long tons)

	1955–59 (average)	1960	1961	1962	1963	1964
Stocks Jan. 1 [1]	28,312	35,521	33,459	36,209	30,876	29,548
Net receipts during year:						
Primary	56,736	50,661	[r] 54,154	50,694	54,411	62,665
Secondary	2,448	2,217	2,897	2,409	2,290	2,524
Scrap	28,103	27,448	[r] 25,755	22,542	22,041	22,985
Total	87,287	80,326	82,806	75,645	78,742	88,174
Available	115,599	115,847	116,265	111,854	109,618	117,722
Stocks December 31 [1]	30,751	33,459	36,209	30,876	29,548	32,427
Total processed during year	84,848	82,388	80,056	80,978	80,070	85,295
Intercompany transactions in scrap	2,193	1,828	1,806	1,893	1,767	2,515
Tin consumed in manufactured products	82,655	80,560	78,250	79,085	78,303	82,780
Primary	53,712	51,530	50,288	54,602	55,209	58,476
Secondary	28,943	29,030	27,962	24,483	23,094	24,304

[r] Revised.

[1] Stocks shown exclude tin in transit or in other warehouses on January 1, as follows: 1955–59 (average), 1,682 tons; 1960, 1,900 tons; 1961, 2,570 tons; 1962, 425 tons; 1963, 115 tons; 1964, 175 tons; and 1965, 220 tons.

TABLE 6.—Tin content of tinplate produced in the United States

Year	Tinplate (hot-dipped)			Tinplate (electrolytic)			Tinplate waste-waste, strips, cobbles, etc., gross weight (short tons)	Total tinplate (all forms)		
	Gross weight (short tons)	Tin content (long tons)	Tin per short ton of plate (pounds)	Gross weight (short tons)	Tin content (long tons)	Tin per short ton of plate (pounds)		Gross weight (short tons)	Tin content (long tons) [1]	Tin per short ton of plate (pounds)
1955–59 (average)	725,820	9,057	27.6	4,277,575	21,897	11.5	389,010	5,392,405	30,954	12.9
1960	454,808	5,443	26.8	5,300,277	27,795	11.8	495,536	6,250,621	33,238	11.9
1961	296,919	3,610	27,2	5,143,839	27,575	12.0	499,258	5,940,016	31,185	11.8
1962	212,525	2,291	24.1	4,989,463	26,417	11.9	545,623	5,747,611	28,708	11.2
1963	174,618	2,188	28.1	4,671,358	26,163	12.6	515,042	5,361,018	28,351	11.9
1964	138,178	1,347	21.8	5,204,541	29,872	12.9	637,481	5,980,200	31,219	11.7

[1] Includes small tonnage of secondary pig tin and tin acquired in chemicals.

TABLE 7.—Consumer receipts of primary tin, by brands

(Long tons)

Year	Banka	English	Katanga	Longhorn	Straits	Others	Total
1955–59 (average)	6,902	5,258	3,795	6	36,653	4,122	56,736
1960	10,065	1,635	1,546		31,355	6,060	50,661
1961	7,763	2,074	579	2,234	37,420	4,084	54,154
1962	8,978	1,448	1,369	1,113	34,341	3,445	50,694
1963	3,393	2,708	1,027	(1)	36,413	[2] 10,870	54,411
1964	1,271	1,441	1,839	(1)	38,713	[2] 19,401	62,665

[1] Included with "Others."

[2] Includes GSA tin not reported under specific brands.

TABLE 8.—Consumption of tin in the United States, by finished products

(Long tons of contained tin)

Product	1963			1964		
	Primary	Secondary	Total	Primary	Secondary	Total
Alloys (miscellaneous)	290	144	434	277	187	464
Babbitt	2,225	1,439	3,664	2,133	1,327	3,460
Bar tin	1,580	88	1,668	1,596	66	1,662
Bronze and brass	4,128	11,784	15,912	4,633	11,951	16,584
Chemicals including tin oxide	1,088	1,350	2,438	1,130	1,678	2,808
Collapsible tubes and foil	992	72	1,064	1,038	61	1,099
Pipe and tubing	28	33	61	29	40	69
Solder	12,856	6,739	19,595	12,617	7,400	20,017
Terne metal	298	263	561	323	295	618
Tinning	2,142	55	2,197	2,187	89	2,276
Tinplate [1]	28,351	----------	28,351	31,219	----------	31,219
Type metal	116	986	1,102	171	1,105	1,276
White metal	1,044	95	1,139	1,066	76	1,142
Other	71	46	117	57	29	86
Total	55,209	23,094	78,303	58,476	24,304	82,780

[1] Includes secondary pig tin and tin acquired in chemicals.

STOCKS

Tinplate mills, holding 83 percent of the plant stocks of pig tin in the United States, increased their inventories by 2,331 long tons. Tin in process at tin mills was 6,112 tons, essentially unchanged from 1963. Pig tin stocks at other plants increased 788 tons.

TABLE 9.—U.S. industry tin stocks

(Long tons)

	1955-59 (average)	1960	1961	1962	1963	1964
Plant raw materials:						
Pig tin:						
Virgin	18,725	20,881	23,679	19,201	17,834	20,926
Secondary	285	257	249	193	220	247
In process [1]	11,741	12,321	12,281	11,482	11,494	11,254
Total	30,751	33,459	36,209	30,876	29,548	32,427
Additional pig tin:						
In transit in United States	1,794	2,570	425	115	175	220
Jobbers-importers	907	1,090	2,675	[2] 2,145	[3] 11,135	[4] 2,950
Afloat to United States	3,218	2,990	3,170	4,140	5,060	1,740
Total	5,919	6,650	6,270	6,400	16,370	4,910
Grand total	36,670	40,109	42,479	37,276	45,918	37,337

[1] Tin content, including scrap.

[2] Includes 1,600 tons, representing bids rejected by GSA, from tin offered by Defense Materials Services of GSA in DMS-MET-20, August 31 (1,600 tons), and in DEM-MET-25, October 19 (1,400 tons). Does not include 1,000 tons representing total of weekly tin offerings in January 1963 (DMS-MET-25, December 31).

[3] Includes GSA as follows: 10,780 tons end of December (bids rejected plus tonnage to be offered through Mar. 27, 1964).

[4] Includes GSA as follows: 1,590 tons end of December 1964, sold but not delivered.

PRICES

Prices for tin reached alltime highs in New York, London, and Penang, reflecting the shortfall of world mine production below consumption. The highest price of Straits tin for prompt delivery in New

York was 217.0 cents per pound on October 29. The lowest price was 131.375 cents per pound on April 8. The average annual price of 157.717 cents per pound is the highest recorded.

The average cash price on the London market was £1,239.4 per long ton, compared with the 1963 average of £909.7 per long ton. The highest price was £1,715.0 on October 30, and the lowest price was £1,020.0 on March 3.

The average price of Straits tin exworks on the Penang market was £1,214.1 per long ton (£892.6 for 1963). The highest quotation was £1,637.2 on October 30, and the lowest was £1,016.1 on January 2 and 3.

TABLE 10.—Monthly prices of Straits tin for prompt delivery in New York

(Cents per pound)

Month	1963			1964		
	High	Low	Average	High	Low	Average
January	111. 500	109. 750	111. 062	135. 500	132. 500	134. 017
February	109. 500	108. 125	108. 542	159. 000	134. 250	140. 125
March	110. 000	108. 750	109. 220	137. 500	132. 000	134. 815
April	115. 125	109. 500	113. 018	134. 875	131. 375	133. 506
May	117. 250	115. 125	116. 648	140. 000	132. 750	134. 850
June	120. 625	114. 500	117. 725	156. 750	138. 875	150. 602
July	116. 750	113. 500	115. 335	166. 000	154. 000	159. 648
August	115. 250	114. 250	114. 841	171. 000	159. 500	161. 667
September	117. 375	114. 750	116. 106	200. 000	171. 000	185. 375
October	124. 625	117. 000	119. 973	217. 000	193. 500	204. 614
November	130. 250	124. 375	127. 037	206. 000	182. 500	190. 271
December	133. 000	126. 625	130. 196	180. 750	154. 750	163. 114
Total	133. 000	108. 125	116. 642	217. 000	131. 375	157. 717

Source: American Metal Market.

FOREIGN TRADE

The principal tin items in the foreign trade of the United States were imports of metallic tin and tin concentrates and exports of tinplate and tin cans. Significant quantities of tin ingot, miscellaneous tin manufactures, and tin compounds were exported. Tin contained in babbitt, solder, type metal, and bronze imported and exported is shown in the "Lead" and "Copper" chapters. Ferrous scrap exports including tinplate and terneplate scrap are not separately classified.

TABLE 11.—U.S. imports for consumption of tin concentrate, by countries

Country	1963		1964	
	Long tons [1] (tin content)	Value	Long tons [1] (tin content)	Value
Bolivia	1, 642	$3, 069, 038	5, 148	$11, 532, 286
Canada	5	205	(2)	590
Mexico	----	----	42	5, 702
Netherlands	----	347	----	----
Thailand	3	7, 603	----	----
Total	1, 650	3, 077, 193	5, 190	11, 538, 578

[1] Reported by the Bureau of the Census as gross weight, adjusted by the Bureau of Mines to tin content.
[2] Less than ½ unit.

Source: Bureau of the Census.

TABLE 12.—U.S. imports for consumption of tin,[1] by countries

Country	1963		1964	
	Long tons	Value (thousands)	Long tons	Value (thousands)
Belgium-Luxembourg	383	$945	229	$838
Bolivia	1,867	4,503	1,034	3,195
Canada	(2)	6	(2)	10
Congo (Léopoldville)	103	28	---	---
Indonesia	1,023	2,473	225	676
Italy	---	---	5	21
Japan	(2)	(2)	967	2,980
Malagasy Republic	20	62	---	---
Malaysia	[r] 36,092	[r] 89,727	24,825	77,589
Netherlands	25	70	523	1,590
Nigeria	2,066	5,085	1,817	5,752
Peru	4	11	76	237
Portugal	105	265	343	1,097
Rhodesia and Malawi	5	12	---	---
Spain	---	---	90	327
United Kingdom	1,590	3,878	1,448	5,066
Uruguay	---	---	(2)	(2)
Total	[r] 43,283	[r] 107,065	31,582	99,378

[r] Revised.
[1] Bars, blocks, pigs, grain, or granulated.
[2] Less than ½ unit.

Source: Bureau of the Census.

TABLE 13.—U.S. exports of tin; imports for consumption and exports of tinplate and terneplate in various forms

Year	Ingots, pigs, and bars				Tinplate and terneplate		Tinplate circles, strips, and cobbles	Tinplate scrap
	Exports		Reexports		Imports	Exports	Exports	Imports
	Long tons	Value (thousands)	Long tons	Value (thousands)	Long tons	Long tons	Long tons	Long tons
1955–59 (average)	733	$1,215	515	$1,111	12,106	536,513	17,399	31,853
1960	608	1,294	249	549	17,612	504,942	20,491	36,352
1961	543	1,264	257	626	13,527	358,707	20,960	29,499
1962	335	840	100	267	46,857	294,510	21,994	18,832
1963	1,544	4,225	81	207	74,055	305,682	20,853	19,486
1964	2,726	9,241	1,315	6,225	80,693	338,588	24,591	23,011

Source: Bureau of the Census.

TABLE 14.—U.S. imports for consumption and exports of miscellaneous tin, tin manufactures, and tin compounds

Year	Miscellaneous tin and manufactures						Tin compounds[1]
	Imports			Exports			
	Tinfoil, tin powder, flitters, metallics, tin and manufactures, n.s.p.f. value (thousands)	Dross, skimmings, scrap, residues, and tin alloys, n.s.p.f.		Tin cans, finished or unfinished		Tin scrap and other tin-bearing material, except tinplate scrap, value (thousands)	Imports (long tons)
		Long tons	Value (thousands)	Long tons	Value (thousands)		
1955-59 (average)	$668	4,565	$8,307	31,865	$15,285	$2,180	8
1960	839	809	1,642	32,875	17,362	1,355	3
1961	676	612	1,299	30,929	15,093	3,352	22
1962	819	2,185	913	25,531	13,927	2,111	58
1963	731	r 2,683	r 1,703	21,595	12,169	2,423	81
1964	300	1,210	714	23,963	14,244	2,151	223

r Revised.

[1] Beginning Jan. 1, 1958, exports no longer separately classified.

Source: Bureau of the Census.

WORLD REVIEW

INTERNATIONAL TIN AGREEMENT

The International Tin Council held four meetings in 1964. The first meeting, in January, considered the current tin position and disposals from the U.S. national stockpile. In March, the percentages and votes of producing member countries were revised. At the same meeting, the council agreed to request that the Secretary-General of the United Nations convene a conference, in the spring of 1965, to prepare a Third International Tin Agreement. The percentages and votes of the consuming member countries were revised at the July meeting. On November 13, the Council raised the tin agreement floor price from £850 per long ton (106.25 cents per pound) to £1,000 per long ton (125 cents per pound); the ceiling price was raised from £1,000 to £1,200 (150 cents per pound); the middle sector of the new range was fixed at £1,050 (131.25 cents per pound) and £1,150 (143.75 cents per pound). The buffer stock held no tin during 1964.

TABLE 15.—Second International Tin Agreement: Percentages and voting powers of producing countries [1]

Country	Percentage	Votes allocated	Country	Percentage	Votes allocated
Bolivia	16.526	165	Nigeria	6.383	67
Congo (Léopoldville)	6.626	69	Thailand	11.020	112
Indonesia	14.383	145			
Malaysia	45.062	442	Total	100.000	1,000

[1] Effective from July 1, 1964, through June 30, 1965. Established at 14th meeting of the Second International Tin Council, Mar. 4-6, 1964.

TABLE 16.—Second International Tin Agreement: Voting power and tonnage of consuming countries [1]

Country	Tonnage	Votes
Australia	4,155	55
Austria	753	14
Belgium	2,991	41
Canada	4,467	59
Denmark	1,541	23
France	10,767	135
India	4,467	59
Italy	5,450	71
Japan	14,678	182
Korea	208	7
Mexico	1,200	19
Netherlands	3,585	48
Spain	1,072	18
Turkey	750	14
United Kingdom	20,772	255
Total	76,856	1,000

[1] Effective from July 1, 1964, through June 30, 1965. Established at the 15th meeting of the Second International Tin Council, July 21–23, 1964.

TABLE 17.—Authority of the tin buffer stock manager

Provisions	Dec. 5, 1963, to Nov. 12, 1964	Revised Nov. 13, 1964
Must sell [1]	£1,000 or higher per long ton (125.0 cents or higher per pound).	£1,200 or higher per long ton (150.0 cents or higher per pound).
Upper range—may sell	£950 to £1,000 per long ton (118.75 to 125.0 cents per pound).	£1,150 to £1.200 per long ton (143.75 to 150.0 cents per pound).
Midrange—abstains from buying or selling.	£900 to £950 per long ton (112.50 to 118.75 cents per pound).	£1,050 to £1,150 per long ton (131.25 to 143.75 cents per pound).
Lower range—may buy	£850 to £900 per long ton (106.25 to 112.50 cents per pound).	£1,000 to £1,050 per long ton (125.0 to 131.25 cents per pound).
Must buy [2]	£850 or lower per long ton (106.25 cents or lower per pound).	£1,000 or lower per long ton (125.0 cents or lower per pound).

[1] If the buffer stock manager has tin.
[2] If the buffer stock manager has money.

REVIEW BY COUNTRIES

Australia.—Tin production increased 19 percent in 1964. Queensland was the principal source.

Tin consumption in 1964 was estimated at about 4,600 tons, compared with 4,660 tons in 1963. Tinplate required 2,534 tons in 1964 and 2,725 in 1963. Total tinplate production was 205,035 tons in 1964 (208,654 tons in 1963). Tinplate production exceeded domestic requirements, and most of the surplus was exported to New Zealand. Imports from the United States were over 1,700 tons.

TABLE 18.—World mine production of tin (content of ore), by countries [1]

(Long tons)

Country	1955–59 (average)	1960	1961	1962	1963	1964 [p]
North America:						
Canada	313	278	500	291	414	159
Mexico	500	372	530	576	1,055	[e] 1,280
United States	30	10	(2)	(2)	(2)	(2)
Total	843	660	(2)	(2)	(2)	(2)
South America:						
Argentina	157	238	515	231	220	[e] 200
Bolivia (exports)	24,820	19,407	20,408	21,492	22,752	24,027
Brazil [3]	278	1,556	582	731	1,150	[e] 1,670
Peru (recoverable)	18	6	14	11	22	22
Total	25,273	21,207	21,519	22,465	24,144	25,919
Europe:						
Czechoslovakia [4]	200	200	200	200	200	200
France	255	21	156	319	276	469
Germany, East [e]	687	720	720	720	720	720
Portugal [5]	1,245	772	729	679	718	657
Spain	504	196	230	231	158	91
U.S.S.R.[6] [7]	12,720	16,000	17,000	17,000	20,000	20,000
United Kingdom	1,089	1,199	1,210	1,181	1,226	1,226
Total [e] [7]	16,700	19,100	20,200	20,300	23,300	23,400
Asia:						
Burma [5]	1,206	1,200	1,130	1,041	1,000	[e] 650
China [6]	22,000	28,000	30,000	28,000	28,000	25,000
Indonesia	27,192	22,596	18,574	17,310	12,947	16,345
Japan	975	842	853	859	857	781
Laos	272	397	335	367	326	336
Malaysia	51,763	51,979	56,028	58,603	59,947	60,004
Thailand	10,887	12,080	13,270	14,679	15,587	15,595
Total [e] [7]	114,300	117,100	120,200	120,900	118,700	118,700
Africa:						
Burundi	---	---	---	---	---	16
Cameroon, Republic of	76	65	65	23	30	30
Congo, Republic of (Brazzaville)	[8] 30	34	46	46	43	34
Congo, Republic of the (Léopoldville)	11,449	8,636	6,314	6,875	6,883	7,688
Morocco	8	10	11	10	10	13
Niger, Republic of	54	53	47	41	54	48
Nigeria	7,700	7,675	7,779	8,210	8,723	8,721
Rhodesia (formerly Southern)	397	642	716	705	498	512
Rwanda	1,664	1,277	1,474	1,400	1,271	[e] 1,680
South Africa, Republic of	1,376	1,276	1,430	1,408	1,530	1,586
South-West Africa	328	261	302	369	443	474
Swaziland	20	6	5	5	3	3
Tanzania (exports)	37	138	163	206	236	277
Uganda	44	32	33	69	163	213
Zambia	---	---	1	5	1	8
Total	23,183	20,105	18,386	19,372	19,888	21,303
Oceania: Australia	2,127	2,202	2,745	2,715	2,852	3,400
World total (estimate)	182,400	180,400	184,100	186,600	190,400	194,200

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[e] Estimate. [p] Preliminary.

[1] This table incorporates some revisions. Data do not add exactly to totals shown because of rounding where estimated figures are included in the detail.

[2] Included with world total to avoid disclosing individual company confidential data.

[3] Estimated by authors of the chapter and in a few instances from the Statistical Bulletin of the International Tin Council, London, England.

[4] Estimate, according to the 50th annual issue of Metal Statistics (Metallgesellschaft) through 1963.

[5] Includes tin content of mixed concentrates.

[6] Estimated smelter production.

[7] Output from U.S.S.R. in Asia included with U.S.S.R. in Europe.

[8] Average annual production 1958–59.

TABLE 19.—World smelter production of tin, by countries [1]
(Long tons)

Country	1955-59 (average)	1960	1961	1962	1963	1964 [p]
North America:						
Mexico	324	365	559	520	1,055	1,145
United States [2]	[3] 11,547	[4] 14,026	[4] 8,917	[4] 5,364	[4] 1,650	[4] 5,190
Total	11,871	14,391	9,476	5,884	2,705	6,335
South America:						
Argentina	40	--------	--------	--------	--------	--------
Bolivia (exports)	501	1,002	2,016	2,023	2,462	3,610
Brazil	1,197	1,311	1,525	2,317	2,051	1.731
Total	1,738	2,313	3,541	4,340	4,513	5,341
Europe:						
Belgium	8,937	7,947	6,002	8,607	7,044	5,458
Germany:						
East [e]	600	600	600	600	600	600
West	715	782	947	1,309	1,052	1,178
Netherlands	22,142	6,393	2,729	4,282	5,762	15,858
Portugal	1,129	601	784	766	766	598
Spain	528	464	731	905	1,614	2,176
U.S.S.R. [5 6 7]	12,720	16,000	17,000	17,000	20,000	20,000
United Kingdom	29,158	26,286	24,449	18,749	17,411	16,849
Total [5 6]	75,900	59,100	53.200	52,200	54,200	62,700
Asia:						
China [5]	22,000	28,000	30.000	28,000	28,000	25,000
Indonesia	1,224	1,977	[5] 2,000	[5] 2,000	[5] 2,000	[5] 1,800
Japan	1,212	1,260	1,644	1,822	1,976	1,954
Malaysia	61,250	76,130	79,114	82,073	84,001	71,351
Total [5 6]	85,700	107,400	112,800	113,900	116,000	100,100
Africa:						
Congo, Republic of the (Léopoldville)	2,969	2,532	275	945	1,441	1,387
Morocco	10	[5] 10	[5] 10	[5] 10	[5] 10	[5] 10
Nigeria	--------	--------	623	8.024	9,051	8,748
South Africa, Republic of	798	622	870	821	938	1,018
Southern Rhodesia	273	611	673	679	499	564
Total	4,050	3,775	2,451	10,479	11,939	11,727
Oceania: Australia	2,001	2,254	2,546	2,704	2,626	3,045
World total (estimate)	181,300	189.200	184,000	189,500	192,000	189,300

[e] Estimate. [p] Preliminary.

[1] This table incorporates some revisions. Data do not add exactly to totals shown because of rounding where estimated figures are included in the detail.

[2] Includes tin content of alloys made directly from ores.

[3] Includes imports of tin concentrates (tin content) into United States for 1958.

[4] Imports into the United States of tin concentrates (tin content). 1963 and 1964 tin content estimated.

[5] Estimated by authors of the chapter and in a few instances from the Statistical Bulletin of the International Tin Council, London, England.

[6] Output from U.S.S.R. in Asia included with U.S.S.R. in Europe.

[7] Includes secondary.

Boliva.—Exports of tin, mostly in concentrate, totaled 24,026 long tons valued at $81 million, an increase of 6 percent in quantity and 42 percent in value. Tin production at nationalized mines increased 17 percent. There were several strikes at the mines during the year. The Paz Government was replaced by a military junta on November 4.

A new schedule of import taxes on tin concentrates exported from Boliva was issued on March 25. The new schedule increased export taxes on concentrates containing less than 20-percent tin and reduced taxes on concentrates containing 21-percent-or-more tin. Sample rate changes follow: 10-percent tin increased about 2 percent, 20-percent tin increased about 3 percent, 30-percent tin decreased about 3 percent, 40-percent tin decreased about 5 percent, and 55-percent-or-more tin decreased about 7.3 percent of gross value.

TABLE 20.—Bolivia: Tin production by nationalized mines

(Long tons of contained tin)

Mine	1962	1963	1964	Mine	1962	1963	1964
Caracoles	776	1,001	999	San Jose	1,058	923	1,247
Catavi	4,076	3,492	4,358	Santa Ana	--------	30	120
Chorolque	673	812	1,166	Santa Fe	614	664	605
Colavi	210	206	214	Tasna	447	510	675
Colquechaca	34	43	46	Unificada	1,293	1,556	2,089
Colquiri	2,314	2,164	2,090	Viloco	674	696	757
Huanuni	2,414	2,586	2,568	Other mines	79	188	335
Japo	90	92	194				
Morococala	241	163	227	Total	14,993	15,126	17,690

Source: U.S. Embassy, La Paz, Bolivia, from data furnished by Corporacion Minera de Bolivia.

TABLE 21.—Bolivia: Exports of tin, by groups

(Long tons of contained tin)

Group	1962	1963	1964	Group	1962	1963	1964
Corporacion Minera de Bolivia [1]	13,219	13,933	14,182	Smelter (tin metal)	[2] 2,021	[2] 2,462	3,610
Banco Minero de Bolivia:				Total	21,492	22,752	24,026
Medium mines	2,731	3,223	3,462				
Small mines	3,521	3,134	2,772				

[1] Decree of Oct. 31, 1952, nationalized the major producers of tin included in this group; namely, Patino Mines & Enterprises Inc., Compagnie Aramayo de Mines en Bolivia, and Maurico Hocschild, S.A.M.I.

[2] Includes tin content of alloys made directly from ore.

Source: U.S. Embassy, La Paz, Bolivia, from data furnished by Corporacion Minera de Bolivia.

TABLE 22.—Bolivia: Exports of tin, by countries

(Long tons of contained tin)

Destination	1962	1963	1964	Destination	1962	1963	1964
Germany, West	1,588	1,666	1,463	United States	3,522	4,292	5,635
Netherlands	859	1,282	1,200	Others	--------	13	10
United Kingdom	15,523	15,499	15,718	Total	21,492	22,752	24,026

Source: U.S. Embassy, La Paz, Bolivia, from data furnished by Corporacion Minera de Bolivia.

Congo (Léopoldville, Republic of the).—Production of tin in concentrate in 1964 was 12 percent greater than in 1963. Exports of tin concentrate in 1964 to Belgium decreased about 35 percent.

Indonesia.—Mine production of tin increased 26 percent in 1964, reversing a 9-year downward trend. The islands of Banka, Billiton, and Singkep furnished 59, 33, and 8 percent, respectively, of the total. All of these operations are owned by the Indonesian Government. Tin in concentrate exports totaled 14,400 tons (estimated) in 1964, almost all going to the Netherlands.

Malaysia.—Mine production was 60,004 long tons, slightly higher than in 1963. Output increased 3,133 tons at gravel-pump mines but decreased 1,847 tons at dredges and 826 tons at open-pit mines. There were 709 active mines at the beginning of 1964 and 900 at yearend. The number of dredges increased from 66 to 69, gravel pump mines increased from 593 to 768, and other mines increased from 50 to 63.

The principal world source of tin continued to be the large plants of the Eastern Smelting Co., Ltd., on the island of Penang; the Straits

Trading Co., Ltd., at Pulau Brani, Singapore; and the Butterworth smelter, Wellesley Province. The concentrate treated was derived mainly from Malaysia and Thailand. Total tin in concentrate available for smelters was 78,057 tons (80,691 tons in 1963). Exports of tin metal were 71,315 tons, mainly from Penang. Some tin from the new Japanese Oriental Tin Smelters, Ltd., was exported from Port Swettenham.

TABLE 23.—Malaysia: Exports of tin in metal, by countries
(Long tons)

Destination	1962	1963	1964	Destination	1962	1963	1964
Argentina	935	1, 291	1, 552	Japan	10, 319	13, 524	14, 370
Australia-New Zealand	2, 218	2, 097	1, 572	Netherlands	2, 395	1, 901	1, 779
Belgium	5, 855	4, 815	740	United Kingdom	1, 955	1, 012	2, 873
Canada	1, 862	3, 851	3, 848	United States	34, 481	35, 579	25, 734
Denmark	184	28	5	Yugoslavia	1, 155	1, 850	1, 581
France	4, 388	3, 423	2, 439	Other countries	5, 773	6, 578	6, 355
Germany, West	655	702	450				
India	4, 478	3, 958	4, 220	Total	81, 393	86, 094	71, 315
Italy	4, 740	5, 485	3, 797				

Source: Malaysia, Department of Statisitcs, Monthly Statistical Bulletin, March 1965.

TABLE 24.—Malaysia: Imports of tin in concentrate, by countries
(Long tons)

Country	1962		1963		1964	
	Gross weight	Tin content	Gross weight	Tin content	Gross weight	Tin content
Burma	1, 982	1, 427	1, 996	1, 441	584	428
Indonesia	17, 635	12, 706	12, 671	9, 133	-	-
Laos	715	514	554	402	678	495
Thailand	12, 801	9, 225	12, 288	8, 868	11, 842	8, 660
Other countries	180	129	456	328	146	107
Total	33, 313	24, 001	27, 965	20, 172	13, 250	9, 690

Stocks of tin metal increased from 2,582 tons at the beginning of 1964 to 2,727 tons at yearend. Tin in concentrate (including mine stocks) decreased from 4,593 tons to 4,003 tons.

Nigeria.—Output of tin in concentrates in 1964 was essentially the same as in 1963. Smelter production decreased 3 percent. Exports of tin metal for January to September 1964, mostly to the United Kingdom and the United States, was 2 percent higher than for the same period in 1963.

Thailand.—Tin continued to be the most important mineral resource of Thailand and ranked as the fourth major export, exceeded in value by rice, rubber, and maize.

U.S.S.R.—Imports from China were 4,000 long tons (estimated), compared with 4,200 tons (revised) in 1963. Tin imports from Indonesia and Western Europe markets were 3,500 tons. Exports from the U.S.S.R. were about 700 tons. Tin consumption was estimated at 26,000 tons. Exports of tinplate were estimated at 75,000 tons, compared with 72,900 tons in 1963. Cuba was the largest market, followed by Bulgaria. Tinplate production was estimated at 380,000 tons.

TABLE 25.—Sino-Soviet bloc: Shipments of tin metal

(Long tons)

Source and destination	1963	1964
From North Viet-Nam to—		
Japan	[r] 139	197
Netherlands	10	----------
Total	[r] 149	197
From China to—		
Austria	96	107
Belgium	----------	90
Columbia	3	----------
Denmark	395	375
Finland	146	----------
France	1, 019	1, 405
Germany, West	990	938
From China to—Continued		
Hong Kong	60	----------
Japan	[r] 1, 174	1, 453
Netherlands	1, 469	409
Norway	116	131
Sweden	266	130
Switzerland	160	88
Syria	29	----------
United Kingdom	1, 157	480
Total	[r] 7, 080	5, 606
Grand total	[r] 7, 229	5, 803

[r] Revised.

Source: Statistical Bulletin of the International Tin Council.

United Kingdom.—The United Kingdom ranked second as a free-world smelter of tin ore, as a consumer of pig tin, and as a producer of tinplate. Most of the concentrate treated came from Bolivia. Primary tin consumption was about 19,500 tons, compared with 20,636 tons in 1963. About 50 percent was used for making tinplate. Tinplate production was 1,159,000 tons, 2 percent less than in 1963 (1,181,700 tons). Of the tinplate produced, 81 percent was electrolytic and 19 percent was hot dipped. Tinplate exports were 385,100 tons, compared with 454,500 tons in 1963. Tinplate shipments to Argentina, Hong Kong, Israel, Portugal, South Africa, South-West Africa, Sweden, Thailand, and Yugoslavia increased. Shipments to China, Denmark, Greece, Italy, New Zealand, Norway, the Philippines, Spain, and the United States decreased. The United States received 19,900 tons, compared with 53,375 tons in 1963. South Africa was the largest buyer of tinplate with 61,180 tons, compared with 43,552 tons in 1963.

Total imports of tin metal, mainly from Nigeria and Malaysia, were 8,883 tons (7,926 tons in 1963). Exports of tin metal, chiefly to France, the United States, and the U.S.S.R., were 6,412 tons.

Pig-tin stocks totaled 3,110 tons at the beginning of 1964 and 3,305 tons at yearend. Stocks of tin in concentrate were 989 tons at the beginning and 1,367 tons at the end of 1964. Stocks of tin in concentrate afloat at yearend were 1,681 tons (1,447 at the beginning of 1964).

TECHNOLOGY

Details of the Bureau of Mines investigation of the Lost River tin deposits in Alaska and results of several thousand feet of diamond core drilling were made available.[2] A geologic study was made of the tin-bearing pegmatites of the Sao Joao del Rei district of Brazil.[3]

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[2] Heide, H. E., and John J. Mulligan. Bureau of Mines Diamond Drill Sampling, Lost River Tin Mine, Seward Peninsula, Alaska. BuMines Open File Rept., 1965. (Report may be consulted at the Central Library of the U.S. Department of the Interior, Washington, D.C., and at the Bureau of Mines Mineral Resource Offices, Juneau and Anchorage, Alaska.)

[3] Heinrich, E. W. Tin-Tantalum-Lithium Pegmatites of the Sao Joao del Rei District, Minas Gerais, Brazil. Econ. Geol., v. 59, No. 6, September-October 1964, pp. 982–1002.

The offshore placer deposits around Indonesia were examined, and dredges to recover tin were designed to operate in 150 feet of water.[4]

The Mount Pleasant deposit in New Brunswick is unusually complex and contains a wide variety of minerals. The major ore mineral is sphalerite. Cassiterite is the chief tin mineral, occurring in mineralized rocks, fluorite masses, and sulfide veins.[5]

Studies showed that 80 to 90 percent of the tin could be recovered from slimed material by hydrogen reduction of the tin, leaching with acidified solutions of copper salts, and precipitation with zinc.[6]

The tin content of ores was upgraded from 0.30 percent to about 6.5 percent by spherical agglomeration using fatty-acid-type collectors.[7]

Tin with a purity of 99.5 percent was recovered from an iron-tin alloy by pressure filtering at temperatures up to 975° C.[8]

The control and electrical systems for tinplating mills and maintenance of hot strip coilers were described.[9] Factors affecting the formation of $FeSn_2$ during the electrodeposition of tin on iron were listed.[10]

The phase equilibria, crystallography, kinetics of formation, and thermal expansion of the columbium-tin system in relation to preparation of superconducting devices were described.[11]

Types of glass produced by the float plate and float sheet tin bath processes were compared.[12]

Additions of tin to cast iron were reported to promote uniformity of hardness, increase strength, and improve machinability of castings subject to wear.[13]

Nucleation rates of the transformation of tin from alpha to beta phases were measured as functions of temperature and alpha tin particle size.[14]

Organotin compounds were used to prevent the fouling of marine instruments.[15]

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[4] World Mining. Indonesia Seeks Answers to Deep Off-Shore Tin deposits. V. 17, No. 9, August 1964, pp. 32–35, 81.

[5] Petruk, W. Mineralogy of the Mount Pleasant Tin Deposit in New Brunswick. Canada Dept. Mines and Tech. Surveys (Ottawa, Canada), TB 56, July 1964, 37 pp.

[6] Burdon, R. G. Extraction of Tin by a Reduction-Leach Precipitation Process. Min. Mag. (London), v. 110, No. 5, May 1964, pp. 314–315.

[7] Farnand, J. R., F. W. Meadus, P. Tymchuk, and I. E. Puddington. The Application of Spherical Agglomeration to the Fractionation of a Tin-Containing Ore. Canadian Met. Quart., v. 3, No. 2, April-June 1964, pp. 123–135.

[8] Ruppert, J. A., and P. M. Sullivan. Recovery of Tin From Hardhead by Filtration. BuMines Rept. of Inv. 6529, 1964, 13 pp.

[9] Bennett, R. K., and J. E. Peebles. Electric Systems Design for Metal Processing Lines. Iron and Steel Eng., v. 41, No. 8, August 1964, pp. 69–88.

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Titanium

By John W. Stamper[1]

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DEVELOPMENT of America's 2,000-mile-per-hour airplane, the A–11, dramatically illustrated the advancements made in the metallurgy and fabrication of titanium metal which make it a leading material of construction for supersonic transports and manned spacecraft. A 26-percent jump in demand for titanium during the year foreshadowed an ever-increasing role for the metal where high performance is required.

From 1960 to 1964 the growth in production capacity for making titanium dioxide pigment in the free world averaged over 7 percent per year. About 17 percent of the capacity added since 1960 was based on the chloride process. Almost 40 percent of the new capacity planned or under construction in 1964 was based on the chloride process.

LEGISLATION AND GOVERNMENT PROGRAMS

The Office of Emergency Planning announced new stockpile objectives for a conventional 3-year war for rutile and titanium sponge metal—51,000 and 20,500 short tons, respectively. About 48,000 tons of rutile was held in various Government stockpiles, but a sufficient quantity of titanium sponge metal was in Government stocks to meet the new objective.

Sales of titanium sponge metal from Defense Production Act inventories totaled 132 short tons. About 16 tons went to the U.S. Naval Research Laboratory, 0.5 tons went to the Watertown Arsenal, and 15 tons went to a firm for production of sonar plates under Navy contract. The remaining 100.5 tons consisted of sponge which had been damaged by a fire at the Sharonville Depot in Ohio.

Government stocks of rutile on December 31, totaled 47,616 tons, of which 18,599 tons was in the national (strategic) stockpile, 17,385 tons was in Defense Production Act (DPA) inventories, and 11,632 tons was in the supplemental stockpile.

Government-held stocks of titanium sponge metal totaled 31,360 tons; 22,339 tons was in DPA inventories, and 9,021 tons was in the supplemental stockpile.

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[1] Commodity specialist, Division of Minerals.

TABLE 1.—Salient titanium statistics

	1955-59 (average)	1960	1961	1962	1963	1964
United States:						
Ilmenite concentrate: [1]						
Mine shipments short tons	658,796	789,237	782,629	809,037	890,071	1,003,997
Value thousands	$13,906	$14,655	$13,320	$13,974	$16,529	$19,178
Imports [2] short tons	378,563	265,645	207,151	166,434	200,880	119,819
Consumption do	819,310	868,080	929,147	944,797	874,986	980,426
Titanium slag: Consumption do	134,952	120,492	130,184	138,205	152,416	128,203
Rutile concentrate:						
Mine shipments do	8,480	9,226	7,664	8,033	11,311	10,547
Value thousands	$1,100	$957	$778	$933	$1,262	$1,016
Imports short tons	42,612	29,235	27,497	35,966	71,990	110,981
Consumption do	34,885	[3] 24,229	[3] 29,548	[3] 31,749	[3] 35,189	79,446
Sponge metal:						
Production do	9,545	5,311	6,727	6,730	7,879	W
Imports for consumption do	1,957	2,231	2,490	925	1,468	2,056
Consumption do	6,247	5,487	6,991	7,136	8,865	11,131
Price: Grade A-1, Dec. 31 per pound	$2.37	$1.60	$1.60	$1.50	$1.50	$1.50
World production:						
Ilmenite concentrate short tons	1,772,400	2,207,000	r 2,314,100	r 2,165,000	r 2,186,400	2,576,400
Rutile concentrate do	114,200	114,200	128,600	150,100	222,200	211,600

r Revised.
W Withheld to avoid disclosing individual company confidential data.
[1] Includes a mixed product containing rutile, leucoxene, and altered ilmenite.
[3] Includes titanium slag.
Excludes use for making titanium dioxide pigment.

DOMESTIC PRODUCTION

Concentrates.—Ilmenite output surpassed 1 million tons for the first time in history, but rutile output dropped 32 percent.

Ilmenite production was reported by American Cyanamid Co., Piney River, Va.; E. I. du Pont de Nemours & Co., Inc., Starke and Lawtey, Fla.; M&T Chemicals, Inc., Hanover County, Va.; National Lead Co., Tahawus, N.Y.; The Glidden Co., Lakehurst, N.J.; Titanium Alloy Manufacturing Division, National Lead Co., Skinner, Fla.; and The Florida Minerals Co., Vero Beach, Fla. Porter Brothers Corp. shipped ilmenite from stockpiles at Boise, Idaho.

Rutile producers were as follows: M&T Chemicals, Inc., Beaver Dam, Va.; Titanium Alloy Manufacturing Division, National Lead Co., Skinner, Fla.; and The Florida Minerals Co., Vero Beach, Fla.

Humphreys Mining Co. planned to begin mining titanium and zirconium minerals on an 1,800-acre tract northeast of Folkston, Ga., at a rate of about 50,000 and 9,000 tons, respectively, in 1965. Du Pont owns the property and will purchase the output.

Metal.—Production of 14,000 tons of titanium ingot and nearly 8,000 tons of mill products set new records.

Commercial producers of titanium sponge metal were E. I. du Pont de Nemours & Co., Inc., Newport, Del.; Reactive Metals Inc., Ashtabula, Ohio; and Titanium Metals Corp. of America (TMCA), Henderson, Nev. Du Pont closed its plant in February, despite the increased demand for titanium.

Titanium melters were Harvey Aluminum, Inc., Torrance, Calif.; Reactive Metals Inc., Niles, Ohio; Oregon Metallurgical Corp., Albany, Oreg.; Crucible Steel Company of America, Midland, Pa.;

Republic Steel Corp., Massillon and Canton, Ohio; and TMCA, Henderson, Nev.

TABLE 2.—Production and mine shipments of titanium concentrates from domestic ores in the United States

Year	Production, short tons (gross weight)	Shipments: Short tons (gross weight)	Shipments: Short tons TiO_2 content	Shipments: Value (thousands)
ILMENITE [1]				
1955-59 (average)	644,681	658,796	346,253	$13,906
1960	786,372	789,237	[r] 417,178	14,655
1961	782,412	782,629	410,191	13,320
1962	807,725	809,037	420,606	13,974
1963	888,400	890,071	[r] 470,983	16,529
1964	1,001,132	1,003,997	526,642	19,178
RUTILE				
1955-59 (average)	9,617	8,480	7,988	$1,100
1960	8,808	9,226	[r] 8,708	957
1961	9,045	7,664	7,251	778
1962	9,981	8,033	7,617	933
1963	11,915	11,311	10,839	1,262
1964	8,062	10,547	10,112	1,016

[r] Revised.

[1] Includes a mixed product containing rutile, leucoxene, and altered ilmenite.

TABLE 3.—Titanium-metal data

(Short tons)

	1960	1961	1962	1963	1964
Sponge metal:					
Production	5,311	6,727	6,730	7,879	W
Imports for consumption	2,231	2,490	925	1,468	2,056
Industry stocks	1,000	1,200	1,300	[r] 1,100	760
Government stocks (DPA inventories)	22,474	22,461	22,461	22,371	22,254
Consumption	5,487	6,991	7,136	8,865	11,131
Scrap-metal consumption	2,527	2,501	3,160	[r] 2,335	2,877
Ingot: [1]					
Production	8,297	9,371	10,400	11,138	13,964
Consumption	7,978	8,878	9,773	10,506	13,501
Mill shape production [2]	5,071	[r] 5,147	[r][3] 6,521	[3] 6,112	[3] 7,708

W Withheld to avoid disclosing individual company confidential data.

[r] Revised.

[1] Includes alloy constituents.

[2] Bureau of the Census and Business and Defense Services Administration, Current Industrial Reports Series BDSAF-263 (64).

[3] Net shipments derived by subtracting the sum of producers' receipts of each mill shape from the industry's gross shipments of that shape. Data not comparable with previous years.

Oregon Metallurgical Corp. produced ingots and castings. The other companies mentioned in the previous paragraph produced and processed ingots into mill products such as sheet, strip, plate, forging billets, and bars. Harvey Aluminum, Inc., produced titanium castings in addition to other mill products. Ladish Co., Cudahy, Wis., processed ingots into forged products.

The Babcock & Wilcox Co., Beaver Falls, Pa., and NTH Products Division of The Carpenter Steel Co., El Cajon, Calif., produced titanium pipe, tubing, and extrusions. Titanium Products Corp. produced seamless titanium pipe at Grosse Point, Mich.

United States Steel Corp. and National Distillers & Chemical Corp. formed a jointly owned company, Reactive Metals Inc., to produce titanium metal and finished products. Titanium sponge metal, ingot, and mill products will be made at National Distillers' plants in Ashtabula and Niles, Ohio. Rolling, forming, and finishing will be done at U.S. Steel's facilities at Pittsburgh, Pa., and Cleveland and Youngstown, Ohio.

Titanium Metals Corporation of America (TMCA) announced the establishment of an applications development center at West Caldwell, N.J. TMCA said that research and development at the center would be directed toward investigation of the properties, corrosion resistance, and weldability of titanium and the assembly of prototype units of small titanium items of equipment to acquaint prospective titanium customers with the metal.

Pigments.—On a gross weight basis, titanium dioxide pigment production was 7 percent higher than that in 1963.

Titanium pigments were produced by the following companies: American Cyanamid Co., Piney River, Va., and Savannah, Ga.; Cabot Titania Corp., Ashtabula, Ohio; The Glidden Co., Baltimore, Md.; E. I. du Pont de Nemours & Co., Inc., Edge Moor, Del., Baltimore, Md., Antioch, Calif., and New Johnsonville, Tenn.; and The New Jersey Zinc Co., Gloucester City, N.J.

TABLE 4.—Titanium pigment data (TiO_2 content)

Year	Production (short tons)	Shipments [1]	
		Quantity (short tons)	Value, f.o.b. (thousands)
1955–59 (average)	450,650	436,905	$228,817
1960	455,583	468,228	252,835
1961	502,879	491,122	262,255
1962	523,201	513,822	270,438
1063	519,458	528,416	278,477
1964	555,211	NA	NA

NA Not available.
[1] Includes interplant transfers.

American Potash & Chemical Corp. expected to complete construction of a 25,000-ton-per-year titanium pigment plant at Aberdeen, Miss., early in 1965. Provisions were made for eventual expansion to 50,000 tons per year. American Cyanamid started construction of a 20,000-ton-per-year expansion of its Savannah, Ga., pigment plant via the chloride process and expected to operate the new facilities in 1965. Du Pont planned a 40-percent increase in capacity of its Edge Moor, Del., titanium pigment plant bringing its total capacity at all plants to more than 225,000 tons per year by 1965.

Pittsburgh Plate Glass Co. and National Lead Co. reportedly planned to build new chloride titanium pigment facilities, in the 20,000- to 25,000-ton-per-year class, by 1967.[2]

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[2] Chemical Week. Titania Outlook: Rosy. Glowing Prospects for Titanium Dioxide Spur New Plant Construction Projects. V. 95, No. 1, July 1, 1964, pp. 61–62, 64, 66.
Oil, Paint and Drug Reporter. Titanium Dioxide Capacity in 1965 Expected To Top 800,000 Tons, a Third of Its Chloride Potential. Vol. 185, No. 20, May 18, 1964, pp. 5, 50.

Welding-Rod Coating.—A total of 292,000 tons of welding rods, containing titaniferous materials in their coatings, was produced. Of the total output, 50 percent contained rutile; 16 percent, ilmenite; 20 percent, a mixture of rutile and manufactured titanium dioxide; 10 percent, manufactured titanium dioxide; 1 percent, slag; and 3 percent, miscellaneous mixtures.

CONSUMPTION AND USES

Concentrates.—Consumption of ilmenite, which was used chiefly for making titanium dioxide pigment by the sulfate process, increased 12 percent; however, titanium slag consumption, which is used chiefly for the same purpose, decreased 15 percent. Rutile consumption, shown in table 5, includes that used for making titanium pigment for the first time since this use was initially reported in 1960.

TABLE 5.—Consumption of titanium concentrates in the United States, by products

(Short tons)

Year and product	Ilmenite [1]		Titanium slag		Rutile	
	Gross weight	Estimated TiO_2 content	Gross weight	Estimated TiO_2 content	Gross weight	Estimated TiO_2 content
1955-59 (average)	819,310	431,131	134,952	95,252	34,885	33,111
1960	868,080	464,614	120,492	85,095	24,229	22,942
1961	929,147	497,514	130,184	92,011	29,548	28,016
1962	944,797	501,196	138,205	98,632	31,749	30,235
1963:						
Pigments	[2] 872,747	[2] 458,128	152,151	108,458	W	W
Titanium metal	(3)	(3)	---	---	14,734	14,021
Welding-rod coating	523	307	207	146	17,444	16,465
Alloys and carbide	1,659	1,036	(4)	(4)	329	314
Ceramics	49	30	---	---	460	430
Fiberglas	---	---	---	---	939	915
Miscellaneous [5]	8	5	58	41	1,283	1,181
Total	874,986	459,506	152,416	108,645	35,189	33,326
1964:						
Pigments	[2] 977,178	[2] 509,403	128,100	91,795	(4)	(4)
Titanium metal	(3)	(3)	---	---	(4)	(4)
Welding-rod coatings	576	341	103	73	19,847	18,751
Alloys and carbide	2,625	1,282	(3)	(3)	(6)	(6)
Ceramics	(4)	(4)	---	---	674	626
Fiberglas	---	---	---	---	813	785
Miscellaneous	47	27	---	---	58,112	56,166
Total	980,426	511,053	128,203	91,868	79,446	76,328

W Figure withheld to avoid disclosing individual company confidential data.

[1] Includes a mixed product containing rutile, leucoxene, and altered ilmenite used to make pigments and metal.

[2] Includes ilmenite that was upgraded to a product containing more than 90 percent TiO_2 for use in making pigments and the losses of ilmenite incurred in upgrading the ilmenite.

[3] Included with "Pigments" to avoid disclosing individual company confidential data.

[4] Included with "Miscellaneous" to avoid disclosing individual company data.

[5] Includes consumption for chemicals and experimental purposes and losses in grinding.

[6] Included with "Fiberglas" to avoid disclosing individual company data.

Metal.—More titanium sponge metal was used by industry than in any other year. According to shipment data, the use of titanium mill products also set a new record—26 percent higher than in 1963.

According to a large titanium producer, the chief use for titanium was in the construction of airframes, whereas formerly it had been used mainly in jet engines and in space applications. The estimated distribution of titanium mill product consumption was as follows:

	Percent
Airframes	39
Jet engines	24
Missiles and space	21
Civilian airplanes	8
Industrial requirements (chemical)	7
Hydrospace	1

Missile and space applications declined slightly in total use partly because of completion of purchase commitments for the Mercury and Gemini spacecrafts. The reliability of titanium in manned spacecraft, such as Mercury and Gemini, has been demonstrated, and significant quantities of the metal are expected to be used in the Apollo spacecraft scheduled to be used in America's third series of manned space flights.

The A–11 superjet airplane, capable of flying three times the speed of sound or about 2,000 miles per hour, was said to be made chiefly of titanium.

Titanium continued in the forefront as a major construction material for the American Supersonic Transport (SST).

The Boeing Aircraft Co. indicated that extensive use of titanium in aircraft designed to travel at 2.2 to 3 times the speed of sound would save over 100,000 pounds in the gross weight of the plane and result in annual savings in operating costs of $870,000 per airplane. Among the basic structural materials considered for use in the SST was titanium alloyed with 8 percent aluminum, 1 percent molybdenum, and 1 percent vanadium which offered the optimum combination of physical and mechanical properties and costs associated with fabrication and raw materials.[3]

Designs for the SST by Boeing, Lockheed Aircraft Corp., and North American Aviation, Inc., were under consideration by the Federal Aviation Agency.[4] Each of the designs call for at least 90,000 pounds of titanium. To realize 96,000 pounds of assemblies in its version, Boeing estimated that it would need to purchase 195,000 pounds of titanium mill products for each airplane to allow for material losses during fabrication.

To help attain top performance in a new Marine Corps assault-transport helicopter, extensive use was made of titanium alloys. Outstanding among some 40 different titanium components used in the craft was the main rotor hub—a one-piece forging, 5 feet across opposing outer bearings, that weighed 225 pounds. The alloy used contained 6 percent aluminum, 4 percent vanadium, and 90 percent titanium.[5]

Utilization of titanium bolts in the gear assembly housing saved 8.5 critical pounds on the weight of propellers being developed for an experimental vertical take-off cargo plane.[6]

What may be the largest application of titanium in the chemical process industry to date was planned in a new acetaldehyde plant at Longview, Tex. The unit is expected to require about 60,000 pounds of titanium sheet and plate. About 20,000 pounds of the sheet metal will be in the form of a titanium lining in a steel jacket produced by Friedr. Krupp, a West German firm. The remainder will be supplied by domestic companies. Two plants for producing terephthalic acid also were expected to use vessels lined or clad with titanium.[7]

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[3] Boeing. Titanium—for Aircraft Structures. D6–8599, March 1964, 43 pp.

[4] Rosenthal, A. G. Titanium on the Rebound. Modern Metals, v. 20, No. 4, May 1964, pp. 27–34.

[5] Bredin, Harold W. Sikorsky Turns to Titanium Forgings for High-Performance Helicopters. Machinery, July 1964, 4 pp.

[6] American Metal Market. Titanium Bolts on Tilt-Wing Plane Save Critical Weight for Designer. V. 71, No. 128, July 2, 1964, p. 13.

A titanium metal producer replaced 14 rubber-lined leaching tanks and saved an estimated $370,000 per year in operating costs by installing a single titanium leaching vessel.[8] The unit, 66 feet long and 8 feet in diameter, eliminated a bottleneck in metal purification, where traces of contaminants are removed from titanium sponge metal by leaching with aqua regia.

Another example of process improvement made possible by titanium was in pulp bleaching plants. It was found that chlorine bleaching solutions can be recycled if titanium is used in the washing operation. The washers, constructed of titanium wire wound around a welded grid frame 8.5 feet in diameter by 12 feet long, were expected to eliminate downtime caused by corrosion and save $30,000 a year.[9]

Pigments.—Consumption of titanium pigments measured by gross weight and using shipments as a gage increased 1 percent over that of 1963. Titanium pigment continued to be used chiefly in paints and paper. The use of titanium pigment in plastics other than in floor coatings as well as in vinyl-coated fabrics and textiles increased by almost 50 percent.

TABLE 6.—Distribution of titanium-pigment shipments, by industries[1]

(Percent)

Industry	1955–59 (average)	1960	1961	1962	1963	1964
Distribution by gross weight:						
Paints, varnishes, and lacquers	65.2	65.1	63.4	61.9	63.3	62.6
Paper	10.9	11.3	12.5	13.0	12.5	12.4
Floor coverings	4.6	4.8	4.5	4.7	4.3	3.9
Rubber	3.7	4.0	4.1	4.2	4.0	3.1
Coated fabrics and textiles (oilcloth, shade cloth, artificial leather, etc.)	2.9	2.8	3.3	3.3	2.0	1.2
Printing ink	1.4	1.3	1.6	1.7	1.6	1.7
Roofing granules	(2)	(2)	(2)	(2)	2.1	1.6
Ceramics	(2)	(2)	(2)	(2)	1.2	1.5
Plastics (except floor covering and vinyl-coated fabrics and textiles)	(2)	(2)	(2)	(2)	2.9	4.4
Other (including export)	11.3	10.7	10.6	11.2	6.1	7.6
Total	100.0	100.0	100.0	100.0	100.0	100.0
Distribution by titanium dioxide content:						
Paints, varnishes, and lacquers	58.3	58.5	57.0	55.3	57.0	56.8
Paper	14.3	14.6	15.7	16.2	15.5	15.2
Floor coverings	5.6	6.2	5.6	5.8	5.2	4.7
Rubber	4.8	4.9	5.1	5.2	4.9	3.7
Coated fabrics and textiles (oilcloth, shade cloth, artificial leather, etc.)	3.7	3.5	4.1	4.0	2.0	1.4
Printing ink	1.9	1.7	2.0	2.1	2.0	2.1
Roofing granules	(2)	(2)	(2)	(2)	2.6	1.9
Ceramics	(2)	(2)	(2)	(2)	1.5	1.9
Plastics (except floor covering and vinyl-coated fabric and textiles)	(2)	(2)	(2)	(2)	3.7	5.4
Other (including export)	11.4	10.6	10.5	11.4	5.6	6.9
Total	100.0	100.0	100.0	100.0	100.0	100.0

[1] Data based on figures supplied to the Bureau of Mines by producers.
[2] Data not available. Included with "Other."

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[7] Chemical Week. Probably the World's Largest Application for Titanium. V. 96, No. 4, Jan. 23, 1965, p. 75.

[8] Chemical Engineering. Titanium Producer Buys His Own Product. V. 72, No. 9, Apr. 26, 1965, pp. 80–82.

[9] Minkler, Ward W. The Future of Titanium in Everyday Uses. Metal Prog., v. 86, No. 4, October 1964, pp. 170–182.

STOCKS

Industry stocks of rutile and titanium slag increased 50 and 13 percent, respectively. Ilmenite inventories also increased. Yearend stocks of titanium sponge metal held by producers, smelters, and semifabricators totaled 760 tons, compared with 1,100 tons (revised) on hand at the end of 1963. Titanium metal scrap held by melters and semifabricators at yearend was 3,500 tons, 100 tons more than in 1963.

TABLE 7.—Stocks of titanium concentrates in the United States, Dec. 31

(Short tons)

Year and stock	Ilmenite		Titanium slag		Rutile	
	Gross weight	TiO_2 content, estimated	Gross weight	TiO_2 content, estimated	Gross weight	TiO_2 content, estimated
1963:						
Mine	27,450	13,675	-----	-----	9,752	9,337
Distributor	224	131	[r] 259	[r] 188	6,469	6,158
Consumer	625,581	346,118	105,541	75,315	76,572	73,073
Total	653,255	359,924	[r] 105,800	[r] 75,503	92,793	88,568
1964:						
Mine	24,586	12,559	-----	-----	7,267	6,956
Distributor	126	73	117	85	10,753	10,324
Consumer	658,895	369,366	119,078	84,836	121,716	117,062
Total	683,607	381,998	119,195	84,921	139,736	134,342

[r] Revised.

PRICES

Concentrates.—The prices, f.o.b. Atlantic seaboard, quoted in E&MI Metal and Mineral Markets for ilmenite (59.5 percent TiO_2) and rutile (94 percent TiO_2) remained unchanged at $23 to $26 per long ton and $104 per short ton, respectively.

Manufactured Titanium Dioxide.—The base prices of rutile and anatase grades of manufactured titanium dioxide pigment and calcium-rutile base titanium pigments were unchanged. Some reduction of the base price was given to purchasers of large lots. The following prices were quoted in the Oil, Paint and Drug Reporter at yearend:

	Price per pound
Anatase, chalk-resitant, regular and ceramic, carlots, delivered	$0.255
Less than carlots, delivered	.265
Rutile, nonchalking, bags, carlots delivered East	.275
Less than carlots, delivered East	.285
Titanium pigment, calcium-rutile base, 30 percent TiO_2, bags carlots, delivered	.09375
Less than carlots, delivered	.09875

Metal.—Quoted prices of titanium sponge metal and mill shapes were unchanged during the year. Prices per pound of titanium sponge metal and mill shapes (f.o.b. mill, commercially pure grades, in lots of 10,000 pounds) were quoted in December as follows:

Sponge metal (99.3+percent Titanium), add extras	$1.32
Sheet	$4.90–$5.10
Strip	4.90– 5.10
Plate	3.80– 4.00
Wire	3.50– 3.80
Forging Billets	2.40– 2.55
Hot-rolled bars	3.15– 3.35

Ferrotitanium.—Nominal prices at yearend for various grades of ferrotitanium were quoted in E&MJ Metal and Mineral Markets as follows:

	Price
Low-carbon:[1]	
Titanium, 25 to 40 percent; carbon, 0.10 percent maximum	$1.35–$1.50
Medium-carbon:[2]	
Titanium, 17 to 21 percent; carbon 3 to 5 percent	375
High-carbon:[2]	
Titanium, 15 to 19 percent; carbon, 6 to 8 percent	310

[1] Price per pound contained titanium in 1-ton lots or more, lump (½-inch, plus), packed; f.o.b. destination northeastern United States.

[2] Price per short ton, carload lots, lump, packed; f.o.b. destination northeastern United States.

FOREIGN TRADE

Imports.—Sharp declines in imports of ilmenite from Australia and titanium slag from Canada resulted in the lowest yearly import rate since 1944. Conversely, rutile imports reached a record 111,000 tons, reflecting increased demand for making titanium dioxide pigment.

General imports of unwrought titanium metal and titanium waste and scrap totaled 2,084 tons, 42 percent more than in 1963. Japan supplied 1,383 tons; United Kingdom, 663 tons; and Canada, 31 tons. The average value of total imports was 87 cents per pound. According to the average value, material from Japan and the United Kingdom was virtually all titanium sponge metal. Material from Canada was virtually all scrap. About 17 tons of the wrought titanium metal

TABLE 8.—U.S. imports for consumption of titanium concentrates[1] by countries

(Short tons)

Country	1955–59 (average)	1960	1961	1962	1963	1964
Illmenite:						
Australia	14,050	33,089	35,362	57,941	52,883	17,122
Canada[2]	170,180	104,243	127,123	108,493	133,885	91,497
India	188,079	128,313	44,666		14,112	11,200
Other countries	6,254			(3)	(3)	
Total:						
Short tons	378,563	265,645	207,151	166,434	200,880	119,819
Value	$8,260,669	$5,066,502	$5,017,911	$4,469,648	$5,087,539	$3,413,175
Rutile:						
Australia	[4] 42,515	27,847	26,047	35,542	71,990	110,981
Other countries	97	1,388	1,450	424		
Total:						
Short tons	[4] 42,612	29,235	27,497	35,966	71,990	110,981
Value	$5,686,349	$3,610,616	$2,544,312	$2,646,174	$4,920,526	$7,723,749

[1] Classified as "ore" by the Bureau of the Census.

[2] Chiefly titanium slag averaging about 70 percent TiO_2.

[3] Less than ½ unit.

[4] Excludes 19 tons rutile content of zirconium ore as reported to the Bureau of Mines by importers.

Source: Bureau of the Census.

imported from the United Kingdom, had an average value of $4 per pound.

Imports of titanium dioxide and pigments totaled 40,710 tons, nearly double the quantity imported in 1963. The chief sources of imported pigment were Japan, 10,247 tons; France, 6,786 tons; and Canada, 3,298 tons. About 223 tons of titanium compounds also was imported, principally from Japan.

Exports.—Titanium dioxide pigment exports increased over the preceding year for the first time since 1956. As in past years, Canada was the principal destination, receiving 12,625 tons of the total. Other countries receiving more than 1,000 tons were as follows: Norway, 2,200 tons; Philippines, 2,200 tons; Australia, 2,000 tons; Netherlands, 1,900 tons; United Kingdom, 1,800 tons; and South Korea, 1,100 tons.

TABLE 9.—U.S. exports of titanium products, by classes

Year	Ores and concentrates		Metal and alloy sponge and scrap		Intermediate mill shapes and mill products, n.e.c.[1]		Ferroalloys		Dioxide and pigments	
	Short tons	Value	Short tons	Value	Short tons	Value	Short tons	Value	Short tons	Value
1955-59 (average)	2, 180	$248, 899	137	$177, 872	441	$5, 861, 877	324	$125, 529	49, 083	$17, 016, 660
1960	1, 260	166, 685	879	868, 846	426	3, 237, 949	245	157, 419	33, 655	10, 000, 884
1961	1, 436	190, 480	886	926, 783	384	2, 702, 322	212	93, 389	31, 104	9, 215, 839
1962	1, 224	166, 987	818	925, 495	561	4, 102, 113	130	95, 265	29, 095	8, 636, 350
1963	1, 212	176, 231	1, 261	1, 232, 245	494	3, 443, 940	211	182, 828	26, 702	8, 051, 111
1964	2, 161	386, 174	1, 817	1, 781, 175	865	4, 997, 963	541	391, 771	29, 359	8, 287, 341

[1] Not elsewhere classified.

Source: Bureau of the Census.

Exports of titanium ores and concentrates were almost double the 1963 exports and included 737 tons to Canada, 661 tons to Norway, and 179 tons to Hong Kong. Most of the remainder was sent to Mexico, Iran, and West Germany.

Titanium metal exports, which according to value consisted mostly of scrap, increased substantially for the third successive year. Of the 1,817 tons exported, the United Kingdom received 1,530 tons; West Germany, 81 tons; and the Netherlands, 74 tons. France, Austria, and Italy received most of the remainder.

Exports of intermediate mill shapes totaled 790 tons and had an average value of $2.34 per pound. Of the total, 559 tons went to Canada, 210 tons to West Germany, and most of the remainder went to the United Kingdom, France, and Sweden. About 75 tons of titanium mill products were exported, chiefly to Canada, France, West Germany, and Sweden.

TABLE 10.—World production of titanium concentrates (ilmenite and rutile) by countries [1] [2]

(Short tons)

Country [1]	1955–59 (average)	1960	1961	1962	1963	1964 [p]
Ilmenite:						
Australia (shipments)	51,406	119,377	186,369	201,034	227,834	343,500
Canada [3]	217,322	389,586	463,361	301,448	379,320	544,721
Ceylon	----------	7,000	11,199	4,652	21,041	50,880
Finland	107,206	92,219	21,272	96,110	103,461	127,937
Gambia	12,340	----------	----------	----------	----------	----------
India	333,756	275,303	192,018	152,241	28,619	11,849
Japan (titanium slag)	6,221	1,444	1,774	578	963	2,161
Malagasy Republic	[4] 905	3,008	3,640	3,510	4,027	[e] 3,300
Malaysia (exports)	93,064	132,255	119,694	113,855	164,656	144,754
Mexico	35	----------	----------	----------	155	----------
Mozambique	[5] 11,400	784	----------	----------	----------	----------
Norway	219,891	258,542	342,723	276,788	267,090	299,608
Portugal	911	1,002	109	75	45	36
Senegal	31,457	24,159	19,286	24,727	13,436	[6] 2,125
South Africa, Republic of	24,747	90,432	99,010	87,096	31,039	----------
Spain	9,883	12,267	33,184	45,935	55,745	44,357
Thailand	[7] 974	----------	----------	----------	----------	----------
United Arab Republic (Egypt)	[e] 6,200	13,228	38,004	49,210	596	23
United States [8]	644,681	786,372	782,412	807,725	888,400	1,001,132
World total ilmenite (estimate) [1] [2]	1,772,400	2,207,000	2,314,100	2,165,000	2,186,400	2,576,400
Rutile:						
Australia	100,926	99,274	113,603	133,499	205,725	201,522
Brazil	257	238	245	144	359	----------
Cameroon	64	----------	----------	----------	----------	----------
India	446	1,082	898	1,781	2,062	2,062
Norway	12	----------	----------	----------	----------	----------
Senegal	410	----------	195	811	780	([6])
South Africa, Republic of	[9] 1,322	3,695	3,483	3,575	1,385	----------
United Arab Republic (Egypt)	[5] 1,157	[e] 1,100	[e] 1,100	198	4	----------
United States	9,617	8,808	9,045	9,981	11,915	8,062
World total rutile (estimate) [1] [2]	114,200	114,200	128,600	150,000	222,200	211,600

[e] Estimate. [p] Preliminary.

[1] Titanium concentrates are produced in Brazil (ilmenite) and in the U.S.S.R., but no reliable figures are available; no estimates are included in the total.

[2] This table incorporates some revisions. Data do not add exactly to totals shown because of rounding where estimated figures are included in the detail.

[3] Represents Ti slag containing approximately 70 to 72 percent TiO_2 and small quantities of "titanium ore" through 1960.

[4] Average annual production 1958–59.

[5] One year only, as 1959 was the first year of commercial production.

[6] Includes ilmenite and rutile.

[7] Average annual production 1956–59.

[8] Includes a mixed product containing ilmenite, leucoxene, and rutile.

[9] Average annual production 1957–59.

WORLD REVIEW

A marked increase in ilmenite output in Canada, the United States, and Australia raised world production to a record 2.6 million tons. Despite increasing demand for rutile, world production declined about 5 percent. However, plans were underway to increase the productive capacity in Australia and Africa.

Estimated free world capacity to produce titanium dioxide pigment shown in table 11 increased from 1.1 million tons per year in 1960 to 1.4 tons per year in 1964. The average annual rate of growth in capacity during the 4-year period was 7.5 percent. Of the 356,000 tons of new capacity added between 1960 and 1964, about 58,000 tons or 16 percent was based on the chloride process. Of the 556,000 tons of additional capacity planned or under construction in 1964, almost 40 percent or 210,000 tons is estimated to be based on the chloride process.

TABLE 11.—Free world titanium dioxide pigment capacity

(Short tons TiO_2)

	Location of plant	Process[1] [2]	Annual capacity		Planned additional capacity
			1960	1964	
North America:					
Canada:					
British Titan Products (Canada) Ltd.	Tracy, Quebec	S	---	22,000	---
Canadian Titanium Pigments, Ltd.	Varennes, Quebec	S	18,000	25,000	---
Continental Titanium Corp.	Baie St. Paul, Quebec	S	---	---	7,300
Total	---	---	18,000	47,000	7,300
Mexico: Pigmentos y Productos Químicos S.A. de C.V.	Tampico, Tamaulipos	S	8,000	8,000	---
United States:					
E. I. du Pont de Nemours & Co., Inc.	Edgemoor, Del	S, C	90,000	90,000	36,000
	Baltimore, Md	S	40,000	40,000	---
	New Johnsonville, Tenn	C	50,000	68,000	---
	Antioch, Calif	C	---	20,000	7,000
National Lead Co	Sayreville, N.J	S, C	157,000	157,000	25,000
	St. Louis, Mo	S	136,000	136,000	---
The Glidden Co	Baltimore, Md	S	56,000	56,000	---
American Cyanamid Co	Piney River, Va	S	18,000	18,000	---
	Savannah, Ga	S, C	72,000	72,000	20,000
The New Jersey Zinc Co	Gloucester City, N.J	S	24,000	46,000	---
American Potash & Chemical Corp.	Aberdeen, Miss	C	---	---	50,000
Cabot Titania Corp	Ashtabula, Ohio	C	---	20,000	20,000
Pittsburgh Plate Glass Co	Natrium, W. Va	C	---	---	25,000
Total	---	---	643,000	723,000	183,000
Total North America	---	---	669,000	778,000	190,300
South America:					
Argentina:					
American Cyanamid and Hafen S.A.	Buenos Aires	NA	---	---	10,000
Titanit Compania Industrial de Pigmentos y Afines.	Pilar	NA	---	---	15,000
Total	---	---	---	---	25,000
Brazil:					
Cia. Quimica Industrial S.A.	Sąo Paulo, Sąo Paulo	S	4,600	4,600	---
DuPont de Brazil, S.A	Victoria, Espirito Santos	NA	---	---	NA
National Lead Co. and Companhia Brasileira de Productos Quimicas Copebras.	Cubatąo, Sąo Paulo	NA	---	---	10,000
Total	---	---	4,600	4,600	10,000
Total South America	---	---	4,600	4,600	35,000
Europe:					
Belgium: Société Chimique des Dérivés du Titane.	Langerbrugge	S	11,000	11,000	5,000
Finland: Vuorikemia Oy	Otanmaki	S	---	16,000	9,000
France:					
Fabriques de Produits Chimiques de Thann et de Mulhouse.	Strasbourg	S, C	13,200	14,000	20,000
Les Produts du Titane, S.A.	Le Havre	S	16,500	36,000	---
British Titan Products Co., Ltd.	Calais	C	---	---	25,000
Total	---	---	29,700	50,000	45,000

See footnotes at end of table.

TABLE 11.—Free world titanium dioxide pigment capacity—Continued

(Short tons TiO$_2$)

	Location of plant	Process [1] [2]	Annual capacity		Planned additional capacity
			1960	1964	
Europe—Continued					
Germany, West:					
Titan G.m.b.H.	Leverkusen	S	77,000	89,000	--------
	Wilhelmshaven	S	--------	--------	140,000
Farbenfabriken Bayer, A.G.	Uerdingen	S	45,000	56,000	--------
Pigment Chemie G.m.b.H.	Homberg	S	--------	20,000	19,800
Total	--------	--------	122,000	165 000	159,800
Italy:					
Soc. Montecatini	Bovisa (Milan)	S	9,900	9,900	--------
	Spinetta Morengo	S	19,800	40,000	--------
Soc. Metalchimica Merodionale Finaziaria Breda	Gallipoli Lecce (Apulia)	N.A.	--------	--------	10,000
Total	--------	--------	29,700	49,900	10,000
Netherlands: N.V. Titaan Dioxydefabriek	Botlek (Rotterdam)	S	--------	12,000	8,000
Norway: Titan Company A/s	Fredrikstad	S	--------	7,500	7,500
Portugal:					
LaPigmentos de Titanium, Lda.	Sines	S	1,000	6,000	9,000
Sociedade de Mineira de Santa Fe	NA	NA	--------	--------	NA
Total	--------	--------	1,000	6,000	9,000
Spain:					
Union Química del Norte de España, S.A.	Axpe-Estremadura Prov.	S	[r] 8,000	8,000	5,100
Chromogenia y Química, S.A.	Barcelona	S	2,800	2,800	--------
Total	--------	--------	10,800	10,800	5,100
United Kingdom:					
British Titan Products Co., Ltd.	Grimsby	S	80,000	100,000	30,000
	Billingham	S, C	22,000	22,000	7,000
Laporte Titanium, Ltd.	Stallingborough	S, C	34,000	56,000	--------
Total	--------	--------	136,000	178,000	37,000
Total Europe	--------	--------	[r] 340,200	506,200	314,400
Asia:					
India: Travancore Titanium Products, Ltd.	Trivandrum, Kerala	S	3,200	16,100	9,000
Japan:					
Titanium Industry Co., Ltd.	Ube, Yamaguchi Pref.	S	7,900	7,900	--------
Teikoku Kako Company, Ltd.	Saidaiji, Okayama Pref.	S	7,900	13,200	1,800
Furukawa Mining Co., Ltd.	Osaka, Osaka Pref.	S	7,900	13,200	1,800
Sakai Chemical Industry Co., Ltd.	Sakai, Osaka Pref.	S	3,000	9,900	100
Ishihara Sangyo Kaisha, Ltd.	Kokkaichi, Mie Pref.	S	30,000	45,000	--------
Fuji Titanium Industry Co., Ltd.	Hiratsuka, Kanagawa Pref	S	2,400	4,800	--------
	Kobe, Hyogo Pref.	S	4,600	4,600	--------
Toho Titanium Co. Ltd. and Ishihara	NA	C	--------	--------	NA
Total	--------	--------	63,700	98,600	3,700
Total Asia	--------	--------	[r] 66,900	114,700	12,700

See footnotes at end of table.

TABLE 11.—Free world titanium dioxide pigment capacity—Continued

(Short tons TiO_2)

	Location of plant	Process [1] [2]	Annual capacity		Planned additional capacity
			1960	1964	
Africa:					
South Africa, Republic of: South African Titan Products (Pty.), Ltd.	Umbogintwini	S		10,000	
Total Africa				10,000	
Oceania:					
Australia:					
Australian Titan Products, Co., Ltd.	Burnie, Tasmania	S	11,000	24,000	3,500
Laporte Titanium (Australia), Ltd.	Bunbury, Western Australia	S		10,000	
Total Oceania			11,000	34,000	3,500
World total			r 1,091,700	1,447,500	555,900

r Revised. NA Not available.
[1] S Sulfate.
[2] C Chloride.

NORTH AMERICA

Canada.—Quebec Iron and Titanium Corp. operated at capacity during the year, producing a record 545,000 tons of titanium slag. The history of the company and a detailed description of its operations were given in a report.[10]

Production of titanium ore for use as heavy aggregate by Continental Titanium Corp. increased markedly and totaled about 27,000 tons. An investment firm reportedly covered equity funds required by the company for the application of a long term loan of $1.5 million to assist financing construction of a 20-ton-per-day titanium dioxide plant at Baie St. Paul, Quebec. Negotiations were underway with several companies interested in investment in the company, including a West German construction firm.[11]

The company stopped construction of a smaller TiO_2 plant in 1961, presumably because of lack of funds.

Mandarin Mines reportedly began a diamond drill program to explore a large magnetic anomaly in Eastern Townships of Quebec, 70 miles east of Montreal. The deposit reportedly contains ilmenite, rutile, and zircon. Multi-Minerals, Ltd., planned to recover phosphoric acid, titanium slag, and pig iron from a apatite deposit near Nemegos, 165 miles northwest of Sudbury, Ontario.[12]

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[10] Canadian Mining Journal. Quebec Iron & Titanium Corp.—Study in Growth. V. 85, No. 11, November 1964, pp. 47–53.

[11] Northern Miner (Toronto, Canada). Continental Titanium Sales Incerase. V. 50, No. 19, July 30, 1964, p. 15.

[12] Canadian Mining Journal (Gardenvale, Quebec, Canada). Canadian Developments. V. 85, No. 8, August 1964, pp. 12, 14. Northern Miner (Toronto, Canada). To Secure Patent Primary Objective for Multi-Minerals. No. 15, July 2, 1964, pp. 13, 20.

EUROPE

Total production of titanium dioxide in the European Economic Community rose from 33,000 tons in 1958 to 210,000 tons in 1962 and was expected to reach 242,000 tons by 1965.[13]

Finland.—Vuorikemia Oy (Mineral Chemicals Co.) used 65,000 tons of sulfuric acid in producing titanium dioxide. The company began expanding capacity of the TiO_2 plant by 50 percent.

France.—British Titan Products, Ltd., a major producer of titanium pigments in the United Kingdom, expected to obtain official approval from the French Government to construct a 25,000-ton-per-year $20 million TiO_2 plant, based on the chloride process at Calais.[14]

According to reports, the French Government required that about 60 percent of the plant's output be sold outside France. Fabriques de Produits Chimiques de Thann et de Mulhouse with a 50,000-ton-per-year sulfate pigment capacity also had plans to construct a 20,000-ton-per-year chloride pigment plant at an undisclosed location.[15]

Société Titanium, a subsidiary of Péchiney, Compagnie de Produits Chimiques et Electrométallurgiques, reportedly produced such items as titanium ingots, mill products, forgings, and stampings at La Praz (Savoie). Titanium sponge was produced at Jarrie (Isère) by Société d'Électrochimie, d'Electro-Métallurgie et des Acieries Electriques d'Ugine. Other firms producing titanium metal products included Société Forgeal, Péchiney, Société des Forges de Bologne, S.N.E.C. M.A., Société Aubert & Duval, and Société Commentrienne D'Aciérs Fins et Speciaux.[16]

Netherlands.—The 22.5 percent interest in Titaan Dioxydefabriek, N.V. 12,000-ton-per-year titanium pigment plant of Cyprus Mines Corp. reportedly was sold to Koninklijke Zout-Ketjen, Hengelo, the Netherlands, for $3.6 million.

Norway.—Production of titanium dioxide pigment was initiated at the new 7,500 ton-per-year plant at Fredrikstad in eastern Norway.

Capacity of the plant, operated by Titan Company A/S, a wholly owned subsidiary of National Lead Co. was being doubled. Output was expected to go chiefly to manufacturers of paint, paper, and plastics in Scandinavian countries. Ilmenite supply for the plant comes from deposits at Sandbekk and Tellnes worked by another National Lead Co. subsidiary, Titania A/S.

An official of the two Norwegian subsidiaries indicated that proven resources at the new Tellnes mine were 350 million tons, and technological problems in smelting the ore to titanium slag and pig iron were solved. Smelting might be done in Norway or in the United Kingdom, where the pig iron made in the process has a potential use.

United Kingdom.—A summary of new developments indicates that plans were made for a new titanium pigment plant on the north bank of the Tees which would result in a 30-percent increase in TiO_2 productive capacity of sulfate process plants, a 50-percent increase in titanium tetrachloride productive capacity, and a new organo-titanates plant of a 300-ton-per-year capacity.[17]

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[13] Chemical Age (London). More Titanium Oxide in Italy. V. 91, No. 2327, Feb. 15, 1964, p. 265.

[14] Oil, Paint and Drug Reporter. British Titan Expecting an Okay on TiO_2 Project. V. 186, No. 22, Nov. 30, 1965, p. 5.

[15] Chemical Age (London). Chloride Route Titanium Oxide Unit for French Firm. V. 91, No. 2346, June 27, 1964, p. 1022.

[16] South African Mining and Engineering Journal. (Johannesburg.) Titanium and Its Industrial Uses Analysed. V. 75, pt. 2, No. 3738, Sept. 25, 1964, pp. 915, 917, 919.

The organic titanium compounds plant, presumably being built by Titanium Intermediates Ltd., a member of the British Titan Products Group, will use titanium tetrachloride as raw material.[18]

Imperial Metal Industries (Kynoch) Ltd. resumed production of titanium sponge metal at Witton and ordered a new vacuum-arc furnace for melting titanium and other metals into ingots from Heraeus Quarzschmelze, G.m.b.H., a West German firm.

Estimated production of titanium sponge was 500 tons.

U.S.S.R.—A report indicates that about 500 tons of titanium metal was imported in 1964. Japan shipped about 60 tons of the total.[19]

ASIA

Ceylon.—Ishihara Sangyo Kaisha, Ltd., the largest titanium pigment producer in Japan, contracted with Ceylon Mineral Sands Corp. for 40,000 tons of ilmenite per year.

There are no harbor facilities at the mine and at the concentrating plant located at Pulmoddai; however, bacause of monsoon conditions, shipping is confined to the period between April and mid-August of each year. The plant was said to be operating at its full capacity of 60,000 tons a year during 1964, but damage to loading facilities at Trincomalee by a cyclone reportedly slowed down operations late in the year.

Mining and concentrating of titanium minerals at the Pulmoddai deposit are discussed under technology.

India.—Travancore Titanium Products, Ltd., expanded annual capacity of its titanium dioxide plant at Trivandrum, Kerala, to 7,100 tons at the end of 1963 and was producing both anatase and rutile grades.[20] Plans were underway to convert more of its capacity to rutile type pigment. The company was licensed to expand total output by 18,000 tons in two equal steps, the first of which was expected to be initiated during the year.

A Canadian firm of consultants (Canselt) reportedly was engaged to study the feasibility of extracting pig iron from the country's ilmenite sands.

A detailed investigation of the mineralogy and treatment of Kerala's beach sand was described.[21]

Japan.—Production of titanium sponge metal by Toho Titanium Co., Ltd., and Osaka Titanium Co., Ltd., was 3,299 tons, an increase of 70 percent over that of 1963. Titanium slag production by Hokuetsu Electric Chemical Co., the only commercial producer, increased 125 percent to 2,161 tons. Osaka produces slag for its own use. Exports of sponge metal, chiefly to the United States, increased 23 percent to 1,735 tons.

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[17] Chemical Age (London). U.K. Chem. Plant Survey. V. 92, No. 2359, Sept. 26, 1964, p. 465.

[18] Chemical Trade Journal and Chemical Engineer (London). Large Organo-Titanium Products Plant for BT Group. V. 154, No. 4011, Apr. 24, 1964, p. 576.

[19] Metal Bulletin (London). Russo-Japanese Trade for 1965. No. 4975, Feb. 23, 1965, p. 34.

[20] Chemical Age (London). India Studies Tariff Protection on Titanium Oxide. V. 91, No. 2332, Mar. 21, 1964, p. 476.

[21] Rao, Y.V.N., G.V.U. Rao, K.K. Majumdar. Recovery of Economic Minerals From Indian Beach Sands. Min. Magazine, v. 110. No. 6, June 1964, pp. 401–409.

Production of titanium slag and sponge metal by Osaka Titanium Company, Ltd., is discussed under technology.

The Toho Titanium Co., Ltd., and Ishihara Sangyo Kaisha planned to establish a joint company with American Potash & Chemical Corp. to make titanium dioxide pigment by the chloride process.[22] Toho, Nippon Soda Co. and Osaka Titanium were said to be conducting research on the chloride process for making titanium pigments.

Ishihara reportedly expanded its rutile-type pigment plant at Yokkaichi by 840 tons per month, bringing total capacity of the plant to about 45,000 tons per year.

Malaya.—Exports of ilmenite increased 45 percent over that of 1963.

TABLE 12.—Malaya: Exports of ilmenite by countries[1]

(Short tons)

Destination	1959	1960	1961	1962	1963
Belgium	11,223	11,466	5,616	----------	19,470
France	8,812	29,599	33,254	34,658	63,194
Italy	345	----------	----------	----------	11
Japan	46,310	57,587	56,802	77,502	81,537
United Kingdom	14,903	33,603	24,019	1,372	112
Other countries	----------	----------	4	324	----------
Total	81,593	132,255	119,695	113,856	164,324

[1] This table incorporates some revisions.

AFRICA

Sierra Leone.—Sherbro Minerals Co., Ltd., owned 80 percent by Pittsburgh Plate Glass Co. and 20 percent by British Titan Products Co., Ltd., was expected to begin producing rutile from a deposit 25 miles inland from the southwest coast late in 1966.[23] Proven reserves of rutile in the area to be mined totaled about 3 million tons, and a potential reserve of 30 million tons of rutile was reported.

The company obtained a $10.2 million development loan from the Export-Import Bank of Washington (U.S.A.) and planned to produce 100,000 tons of rutile concentrate per year. The ore will be mined by a dredging operation and partially deslimed and concentrated on the dredge with cyclones and sluices. The concentrate will be separated electrostatically and magnetically in a dry plant on shore. The rutile will be hauled 16 miles by covered hopper trucks to 2,000-ton covered barges, which will be towed an additional 18 miles to deep water for transfer to oceangoing ships in the Sherbo Estuary.

Senegal.—The Office of Mines of the Government of Senegal was reportedly interested in making known the results of studies of the ilmenite deposit along the coast north of Dakar. Reserves were estimated at 5 million tons of ilmenite, 600,000 tons of zircon, and 100,000 tons of rutile. The heavy minerals reportedly contained a high percentage of chronium, which is detrimental in some processing techniques for making titanium pigments.

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[22] Chemical Age (London). Japanese Firms Seek Chloride Process for Titanium Oxide. V. 91, No. 2344, June 13, 1964, p. 950.

[23] Chemical Engineering. U.S. Company Spearheads an African Rutile Venture. V. 71, No. 16, Aug. 17, 1964, p. 84.

Engineering and Mining Journal. New Rutile Source Is World's Largest. V. 165, No. 8, August 1964, p. 103.

Sherbro Moves Ahead With African Rutile Mining Project. V. 165, No. 12, December 1964, p. 112.

Skilling's Mining Review. Rutile Development in Sierra Leone, Africa. V. 53, No. 48, Nov. 28, 1964, pp. 12–13.

South Africa, Republic of.—The Government closed the Umgababa Minerals, Ltd., ilmenite and rutile mine at Umbogintwini, Natal, in May 1963 when the company was unable to clean up the effluent from the plant that was polluting the highly developed resort industry in the area. The remaining reserve of ilmenite in the area reportedly does not exceed 2 million tons.

The South African Titan Products (Pty.), Ltd., titanium dioxide plant at Umbogintwini had stockpiled a year's supply of ilmenite but was importing Australian ilmenite in 1964.

United Arab Republic (Egypt).—The Egyptian Black Sands Co. planned expansion of its mine near the mouth of the Rosetta Branch of the Nile River to recover 100,000 to 150,000 tons of ilmenite from which about 65,000 tons of a "synthetic rutile" would be produced. In one 12-square-kilometer beach sand area, borehole samples indicated that about 37 million tons of economic minerals (ilmenite, zircon, rutile, monazite, magnetite) were present. A virtually unlimited quantity of titanium minerals was inferred from the large beach area.

OCEANIA

Australia.—Production of ilmenite reached a new record. West Coast rutile producers continued to expand productive capacity and extend leases beyond present operations. A new ilmenite mining operation was established on the West Coast and one was planned on the East Coast.

About 202,000 tons of rutile was produced by the following companies operating a number of mines and concentrating plants on the east coast from 150 miles north of Brisbane to 500 miles south:

Company	Ownership	Operating location
N.S.W. Rutile Mining Co. Pty., Ltd	Murphy family	Cudgen, N.S.W.
Titanium Alloy Manufacturing Division.	National Lead Co	Cudgen, N.S.W.
Mineral Deposits Pty., Ltd	National Lead Co	Southport, Qld & Port Macquarie, N.S.W.
Associated Minerals Consolidated, Ltd	Consolidated Gold Fields of South Africa, Ltd.	Cudgen, N.S.W.
Zircon Rutile Byron Bay Pty., Ltd		Byron Bay, N.S.W.
Yong Minerals Ltd		Newcastle, N.S.W.
Rutile & Zircon Mines (Newcastle) Ltd	Peko-Wallsend Investment Ltd. & Coffs Harbour Rutile N.L.	Newcastle, N.S.W.
Cudgen RZ Pty	Foyster family	Cudgen, N.S.W.
Titanium & Zirconium Industries Pty., Ltd.	Conzine Rio Tinto	Stradbroke, Is. Qld.

Source: Mining Engineering. Rutile—Zircon Mining on East Coast Beaches. V. 16, No. 10, October 1964, pp. 109–110.

TABLE 13.—Australia: Exports of rutile concentrate by countries

(Short tons)

Destination	1963	Jan.-June 1964
Belgium	3,212	(1)
France	6,938	(1)
Germany, West	4,972	(1)
Italy	7,158	(1)
Japan	12,460	(1)
Netherlands	10,626	6,742
Sweden	4,392	(1)
United Kingdom	16,386	7,568
United States	88,234	18,000
Other countries	18,671	32,184
Total	173,049	64,494

[1] Data not separately recorded. Included in other countries.

TABLE 14.—Australia: Exports of ilmenite concentrate by countries

(Short tons)

Destination	1963	Jan.-June 1964
France	1	NA
Japan	25,337	
Netherlands	1,127	
United Kingdom	80,032	
United States	40,430	
Other countries	23,358	
Total	170,285	113,647

NA Not available.

Rutile & Zircon Mines (Newcastle), Ltd., was expanding capacity of its wet concentration plant to handle 17 million tons of sand per year to meet the delivery schedules under its contract with Du Pont, which reportedly were as follows:

Year ended October 1:	*U.S. delivery, short tons*
1963	30,000
1964	40,000
1965	50,000
1966	50,000
1967	50,000

The contract reportedly called for U.S. delivery of the above quantities plus or minus 10 percent in any one year.[24] Operation of the mine and concentration plant was described.[25]

Titanium Alloy Manufacturing Co. Pty., Ltd., has leases covering 3,500 acres on Fraser Island and at Inskip Point and planned to begin mining sand for rutile and zircon at Tin Can Bay, near Gympie, Queensland, about 100 miles north of Brisbane.[26]

Under the Associated Minerals Consolidated 10-year contract with American Potash & Chemical Corp. for 220,000 tons of rutile, the first

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[24] World Mining (Australia). New South Wales Rutile-Zircon Production Is Being Expanded. V. 17, No. 11, October 1964, pp. 92, 93.

[25] Canadian Mining Journal (Canada). Beach Sand Mining at Newcastle. V. 85, No. 11, November 1964, pp. 55–56.

[26] Metal Bulletin (London). Rutile and Zircon in Queensland. No. 4886, Apr. 7, 1964, p. 21.

10,000 ton shipment was made in December. The company reported that work has started on new production units in the Newcastle area (with a separating plant at Hexham) to substantially expand its present capacity of 50,000 tons of rutile per year. Reserves of the company recoverable under 1964 economic conditions were reported as 1.4 million tons of rutile.

Mineral Deposits Pty., Ltd., was investigating deposits on Kangaroo Island in South Australia, for titanium minerals.

Titanium and Zirconium Industries Pty., Ltd., started work to double the capacity of one of its dredge concentrators to 30,000 tons of rutile per year.

Murphyores, Inc., Pty., Ltd., a wholly owned Australian mining company, and associate of N.S.W. Rutile Mining Co. Pty., Ltd., announced plans to commence production of ilmenite at Gladstone, Central Queensland. Plant design was to be completed in 1965, and by 1966 construction of a modern plant with an annual production of 200,000 tons of ilmenite was planned. Capital outlay of A£2,000,000 was anticipated.

The company reportedly held extensive chrome-free ilmenite leases on the Central Queensland coast and has been exploring the mineral bearing areas for several years.

Australian Titan Products Co., Ltd., announced that annual capacity of its titanium dioxide plant at Burnie, Tasmania, would be increased from 24,000 tons to 27,500 tons.

Western Mineral Sands, Pty., jointly owned by Australian Titan Products and Westralian Oil, Ltd., established a new ilmenite mine near Bunbury, Western Australia, capable of producing 100,000 tons of ilmenite annually.[27]

Western Titanium, N.L., planned to start production of a high titanium dioxide product from ilmenite, presumably using a process developed by the West Australian Government Chemical Laboratories and described under Technology.[28]

The company also indicated that capacity of its mine and concentrating plant near Capel, West Australia, would be increased 10 percent to about 130,000 tons of ilmenite per year.

New Zealand.—The Blue Tasman Syndicate, established in 1962, planned to construct a A£120,000 plant to produce titanium slag on the West Coast of South Island.[29] The Japanese reportedly offered to provide shipping and a market for the slag.

TECHNOLOGY

The mineralogy and origin of the titaniferous deposit at Pluma Hidalgo, Oaxaca, Mexico, were discussed in a report.[30] The report stated that the deposit, which received considerable publicity in the mid-1950's as a possible source of rutile, has been studied by Republic Steel Corp., but no lodes or ore shoots with any predictable continuity were found. While this appeared to preclude underground mining, it was believed that any future exploration of the area should be directed to the possibility of surface mining techniques.

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[27] Colliery Guardian (London). New Ilmenite Plant. V. 209, No. 5386, July 10, 1964, p. 45.

[28] Metal Bulletin (London). More About WT's Upgraded Ilmenite. No. 4905, June 16, 1964, p. 20.

[29] Foreign Trade (Ottawa, Canada). Titanium. V. 121, No. 13, June 27, 1964, p. 49.

[30] Paulson, Edwin G. Mineralogy and Origin of the Titaniferous Deposit at Pluma Hidalgo, Oaxaca, Mexico. Econ. Geol., v. 59, No. 5, August 1964, pp. 753–767.

The sand deposit at Pulmoddai, Ceylon, averages about 200 feet in width and extends 4 miles in a north-south direction.[31] Small dune-like concentrations are formed in certain places throughout the deposit. Depth varies from 5 to 10 feet. Estimated reserves are 3.5 to 4 million tons of ilmenite.

Composition of the beach sand was reported as follows:

Mineral:	Percent
Ilmenite	78–80
Rutile	8–12
Zircon	8–10
Quartz	1–2
Magnetite	2–3

The sands are excavated and piled along the beach into large dunes and collected by dumpers of 4.5-cubic-yard capacity. Although over 30,000 tons of sand has been treated since the mine opened in 1961, operations have been confined to an area of 1,000 yards along the beach. The current mining area was excavated five times during 1961–63 as wave action filled the excavated pits in a few months time with material essentially having the same composition.

The beach sand is passed through a 60-mesh screen to remove lime shells and other gangue materials and is separated electromagnetically to yield an ilmenite product and a product containing the rutile, zircon, and other minerals.

Analysis of the ilmenite concentrate was reported to be as follows:

Constituent:	Percent
TiO_2	54.4
Fe (total iron)	30.75
FeO	20.07
Fe_2O_3	21.66
MnO	0.94
Cr_2O_3	0.091
S	0.016
P	0.024

The rutile–zircon product is being stockpiled.

West Australian Government Chemical Laboratories described pilot plant tests of a two-stage process for removing iron oxides from ilmenite concentrate from the Capel area of West Australia.[32] In the first stage the iron oxides are reduced with solid carbon (coal) to metallic iron. Experimental reductions in crucibles, a fluidized bed, and a small pilot plant rotary kiln were described. The material was then agitated in aerated water. The iron oxide thus formed was easily separated by decantation. The titanium oxide product contained about 90 percent TiO_2. An Australian firm, Western Titanium N.L., reportedly operated a semicommerical plant using the process.

An abundance of large but complex deposits of titaniferous ores in the U.S.S.R. has led to substantial research on electric smelting processes to recover the titanium. Recent studies are described in a comprehensive report.[33] Tests with a 3,000-KVA furnace indicated that productivity was higher using a briquetted charge than when using a powdered charge and specific electric power consumption was less. Active reducing agents with high electrical resistance such as low-ash gaseous coals and anthracite were found to be the most effective, although any carboniferous material such as coke could be used. Slags produced contained 80 to 90 percent TiO_2. The FeO content of most of the slags was less than 5 percent.

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[31] Kanapathipillai, K. C. Ilmenite From the East Coast of Ceylon. Min. Mag. (London), v. 110, No. 4, April 1964, pp. 239–241.

[32] Becher, R. G., R. G. Canning, B. A. Goodheart, and S. Uusna. A New Process for Upgrading Ilmenitic Mineral Sands. Mining—Paper 3, Pres. at Annual Conf. of the Aus. I.M.M., Apr. 23, 1964, 21 pp.

Laboratory tests showed that carbon monoxide plays only a minor role in the reduction of titania from titaniferous ores.[34] However, volatile materials liberated from certain coals used in reducing titanium concentrates apparently were important reducing agents.[35]

Additional details on the mining and smelting operations of Q.I.T. in Quebec, Canada, were published.[36] The electric furnaces, 54 feet long, 24 feet wide, and 16 feet high, are lined with several courses of basic refractories. Feed boxes distributed around the top of each furnace supply the charge mixture consisting of about seven parts of concentrated calcined ore to one part of anthracite coal. Titanium slag and molten iron which settles to the bottom of the furnace are tapped at irregular intervals. In a typical day 300 to 400 tons of ore and 40 to 60 tons of coal are charged in the furnace, yielding 140 to 190 tons of slag, 100 to 140 tons of iron, and about 3 million cubic feet of gas containing 85 percent carbon monoxide, 10 percent hydrogen, and 3 percent nitrogen.

Thin hard coatings of titanium carbide reportedly increased the life of tools, dies, punches, and other steel products.[37] The coating process consists of reacting gaseous titanium tetrachloride and hydrocarbons on the heated surface of the parts. Both internal and external surfaces receive a uniform coating.

Titanium Tetrachloride.—A process for producing titanium tetrachloride by thermal decomposition of a complex, double salt, potassium hexachlorotitanate, was described.[38] The process utilizes the titanium sulfate resulting from the digestion of ilmenite with sulfuric acid in the sulfate process for making titanium dioxide pigment. The titanium sulfate solution was treated with hydrochloric acid to precipitate any remaining iron as ferric chloride and to provide enough chlorine to make titanium tetrachloride. Solid potassium chloride is added, forming the chlorotitanate, which is filtered and washed. On heating, the complex salt decomposes to titanium tetrachloride and potassium chloride, which can be recycled.

An economic supply of hydrochloric acid and practical utilization of the byproduct chlorine, when the tetrachloride is converted to pigment or metal, present problems in development of the process. However, in view of the reported selectivity of the reaction between potassium and titanium chlorides and the high purity of the resulting complex salt, it appears that this compound will have a significant role in the future technology of titanium.

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[33] Reznichenko, V. A., and others. The Metallurgy of Titanium: Investigation of Electric Melting of Titanium Slags. U.S. Dept. of Commerce, Office of Tech. Services, J.P.R.S.–22,924, TT 64–21403. Jan. 27, 1964, 183 pp.

[34] Ohno, Atsumi, and H. U. Ross. The Reduction of Titanium Dioxide in Titaniferous Slags. Canadian Metallurgical Quarterly. V. 3, No. 3, July–Sept., 1965, 257–267.

[35] Rapoport, M. B., and V. M. Kozlov. Effect of the Properties of Carbon Materials on the Reduction of Iron-Titanium Concentrates Zhurnal Prikladnoi Khimii, v. 36, No. 7, July 1963, pp. 1442–1453.

[36] Guimond, Roger. Titanium and Q.I.T. Mining in Canada (Winnipeg, Canada), v. 37, No. 11, November 1964, pp. 11–16; 19–21.

[37] Iron Age. Carbide Takes the Vapor Route for Coating Metal Tools. V. 194, No. 12, Sept. 17, 1964, pp. 82–83.

[38] European Chemical News (London). TiO_2 Sulphate Process Linked to Chloride Route. V. 5, No. 115, Mar. 27, 1964, p. 26.

Pigment.—Patents were awarded on methods for introducing various additives, such as alumina,[39] titania,[40] and zirconium [41] phosphates, and perchlorate salts [42] to titanium dioxide pigments to improve their chalking, glossing, or other properties.

A report indicated that titanium dioxide added to glass is beneficial in shifting the absorption edge at the blue end of the spectrum to longer wavelengths. Depending on the quantity of TiO_2 added to glass compositions can be produced which absorb all of a major portion of the ultraviolet radiation, thus aiding in preventing spoilage by such rays of food or beverage in glass containers.[43]

TiO_2 additions to glass lowers the viscosity when molten, increases the softening point, improves the chemical durability, and increases the refractive index and dielectric constant.

Metal.—Development of the 2,000 mile-per-hour-plus airplane, the A–11, dramatically illustrated the advancements made in the metallurgy and fabrication of titanium in recent years.[44]

Annealed titanium forgings weighing more than 50 pounds were selected for use in airframe structures. The minimum-cross-section of extruded titanium shapes, which was 0.25 inch as recently as 1960, was lowered to 0.125 inch, and indications were that sizes as low as 0.063 inch would soon be available. Heat-treated titanium forms as long as 21 feet and annealed titanium forms as long as 40 feet were available in five alloy grades. Chemical milling of titanium was reportedly less costly than steel and about the same as aluminum.

Fabricating of titanium for the second stage rocket cases of the Minuteman missile was easier than with steel because pre- and post-heating of weld areas are not required with titanium. Moreover, unlike steel, titanium can be machined in the heat-treated condition. Ends of rocket cases for the Titan 3 missile were one piece titanium forgings weighing 619 pounds. Modification of established alloy grades to control the interstitial content improved the notch toughness at cryogenic temperatures.

The yield strength of titanium was increased as much as 60 percent by taking advantage of the anisotropy of some titanium alloys.[45] By activating the surface of titanium in said solutions containing nickel chloride, investigators at the Marshall Space Flight Center plated titanium with copper, nickel, and chromium using conventional processes.[46] Other investigators used ammonium fluoride solutions containing zinc, nickel or cobalt fluorides to etch and activate the surface.[47]

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[39] Chemical Trade Journal and Chemical Engineer (London). Patent Abstracts. (Titanium Dioxide; Laporte Titanium Ltd.; British Patent 963,390.) V. 155, No. 4039, Nov. 6, 1963, p. 639.

[40] Whately, Walter R. (assigned to American Cyanamid Co.). Treatment of Titanium Dioxide. U.S. Patent 3,127,280, Mar. 31, 1964.

[41] Whately, Walter R. (assigned to American Cyanamid Co.). Titanium Dioxide Pigments. U.S. Patent 2,141,788, July 21, 1964.

[42] Kingsbury, Franklin L. (assigned to National Lead Co.). Method for Treating Titanium Dioxide Pigments to Obtain High Gloss Properties. U.S. Patent 3,152,000, Oct. 6, 1964.

[43] Strimple, J. H. Titanium Dioxide. Its Effect on the Transmission of Various Glass. Glass Industry, v. 45, No. 4, April 1964, pp. 193–196.

[44] Journal of Metals. Mastery of the Metallurgy and Fabrication of Titanium. V. 16, No. 4, April 1964, pp. 322–323.

Space Aeronautics. The Supersonic Transport. A Special Report. April 1964, p. 11.

Steel. Titanium: Ready for Commercial Breakthrough. V. 155, No. 16, Oct. 19, 1964, pp. 105–114.

[45] Ernst, R. H., and R. A. Wood. Review of Recent Developments—Titanium and Titanium Alloys. Battelle Memorial Institute, Defense Metals Information Center, June 12, 1964, 3 pp.

The Bureau of Mines developed a water-free expendable graphite mold material for casting titanium that is adaptable to standard foundry techniques such as core blowing and hand ramming. The material, consisting of powdered graphite, cornstarch, dextrin, cereal binder, linseed oil, and Carbowax-4000, is mulled in a carbon dioxide atmosphere and cured and fired at temperatures less than 960° C.[48]

A report on the welding of thick titanium plate revealed that submerged-arc and electroslag welding processes, which normally are not considered for welding titanium in the United States, are used in the U.S.S.R. Inert-gas welding also is used in the U.S.S.R. but its use is restricted to titanium less than 0.08 inch thick. Submerged-arc welding is used for joining titanium with thicknesses in the range of 0.08 to about 2 inches. For thicknesses over 2 inches electroslag welding is used.[49]

The phenomena of hot-salt stress-corrosion cracking of titanium alloys, which has been observed in laboratory tests, was examined as a possible limiting factor in the use of titanium in structural applications in the Super-Sonic Transport (SST).[50] While no failures in service have been attributed to this potential problem, it is an important factor to be considered when the high temperatures and stresses are encountered. The study indicated that even if titanium alloys are found to be susceptible to this type of failure under operating conditions predicted for the SST, practical measures can be developed to prevent failures.

A laboratory electrolytic cell to produce titanium from titanium tetrachloride, utilizing an alundum diaphragm to separate the anode and cathode compartments, was described.[51] Metal quality was improved by delaying the immersion of the main deposition cathode for a considerable period after starting electrolysis. The Bureau of Mines discussed cells for electrorefining off-grade titanium.[52] In one cell about 2 tons of pure titanium metal with a Brinell hardness number (Bhn) of 80 or less was produced. Some metal of less than 60 Bhn was produced. Internally heated cells used only 25 kilowatts to maintain 3,500 pounds of electrolyte at 850° C, compared with 35 kilowatts required to keep 400 pounds at 850° C, using external heating. The Bureau also determined that the transfer of nickel, tin, and bismuth from the anode to the cathode in titanium electrorefining cells was very low. Copper transfer was 0.6 to 0.8 percent in chloride systems. High-purity titanium metal was produced from molten titanium-nickel alloys. Manganese deposited with the titanium and high-purity titanium-manganese alloys were produced.[53]

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[46] Metal Progress. Electroplating Titanium. V. 86, No. 1, July 1964, pp. 167–168.

[47] Andryushchenko, F. K., and I. E. Vlasenko. Surface Treatment of Titanium Before Chrome Plating. Zhurnal Prikladnoi Khimii, v. 36, No. 4, April 1963, pp. 921–922.

[48] Ausmus, S. L., and R. A. Beall. Expendable Casting Molds for Reactive Metals. BuMines Rept. of Inv. 6509, 1964, 44 pp.

[49] Mishler, H. W. A Review of Available Information on the Welding of Thick Plate in the U.S.S.R. Battelle Memorial Institute, Defense Metals Information Center, Metals Joining Division, DMIC Memorandum 188, Mar. 6, 1964, 21 pp.

[50] Boyd, W. K., and F. W. Fink. The Phenomenon of Hot-Salt Stress-Corrosion Cracking of Titanium Alloys. National Aeronautics and Space Administration, NASA CR–117, October 1964, 44 pages.

[51] Rand, Myron J., and Lawrence, J. Reimert (New Jersey Zinc Co. Palmerton, Pa.). Electrolytic Titanium From $TiCl_4$ Operation of a Reliable Laboratory Cell. J. Electrochem. Soc., v. 111, No. 4, April 1964, pp. 429–434.

[52] Leone, Oliver Q. Observations in the Development of Titanium-Refining Cells. BuMines Rept. of Inv. 6432, 1964, 27 pp.

Comprehensive information on the corrosion properties of titanium and its alloys, determined by the Bureau of Mines and obtained from published sources, was given in a report.[54]

The dangers and potential dangers of handling certain forms of titanium under various conditions were discussed in a report.[55] Mixtures of air and titanium dust containing more than 0.05 ounce of titanium per cubic foot of air can readily explode at considerably lower temperatures than milled magnesium and aluminum. The minimum spark energy required also is much lower.[56]

Production of titanium sponge metal from titanium slag by Osaka Titanium Co., Ltd. (OTC) at Amagasaki, Japan, was described.[57] OTC produces titanium slag averaging about 58.7 percent titanium (98 on a TiO_2 basis) from ilmenite at a cost of approximately $82 per short ton. A mixture of about 6.5 parts of ilmenite (55 percent TiO_2) and 1 part of petroleum coke is smelted in a 1500 kva furnace equipped with 3 electrodes of the Soderberg type. One electrode is used for open-arc melting and the other two are employed either for preliminary resistance heating or for arc-melting. The furnace is lined and kept in operating condition with a skull of high titanium slag. An oxygen lancing technique is employed to reduce viscosity of the slag. Monthly production capacity of the furnace is 220 short tons of slag.

Titanium tetrachloride is produced by chlorinating a briquetted mixture of 70 percent titanium slag and/or rutile with 20 percent petroleum coke and 10 percent pitch.

The titanium tetrachloride is reduced with magnesium metal under a vacuum as in the United States. However, OTC uses vacuum distillation to remove excess magnesium and magnesium chloride from the titanium sponge, and unlike producers in the United States, it places the reaction vessel inside a vacuum furnace to facilitate placing the charge into a vacuum distillation furnace. The purefied sponge is crushed to 0.5-inch mesh size. Magnesium metal and chlorine are recovered from the magnesium chloride formed in the reaction and recycled.

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[53] Kleespies, E. K., and T. A. Henrie. Transfer of Selected Metals in Titanium Electrorefining. BuMines Rept. of Inv. 6437, 1964, 9 pp.

[54] Schlain, David. Corrosion Properties of Titanium and Its Alloys. BuMines Bull. 619, 1964, 227 pp.

[55] Metal Industry (London). Some Hazards When Handling Titanium. V. 104, No. 24, June 11, 1964, pp. 794–795.

[56] See work cited in footnote 55.

[57] Noda, Toshio. Titanium From Slag in Japan. Pres. at ann. meeting of the Am. Institute of Mining, Metallurgical, and Petroleum Engineers, New York, Feb. 16–20, 1964, 16 pp.

Tungsten

By Richard F. Stevens, Jr.[1]

⁂

DURING 1964 the tungsten ore and concentrate market improved significantly. The foreign price increased three times from the previous low of $7 per short-ton unit and estimated world production increased slightly. Even at the increased price, however, few of the mines which had shut down during the preceding 2 years were reopened.

The two major factors influencing the improved tungsten market during the year were the relative absence of Chinese tungsten exports and the shortage of molybdenum, which caused many firms to substitute tungsten.

TABLE 1.—Salient tungsten statistics

(Thousand pounds of contained tungsten)

	1955–59 (average)	1960	1961	1962	1963	1964
United States:						
Mine production	[1] 12,875	6,669	8,188	8,280	W	W
Mine shipments	8,396	6,972	7,847	8,021	5,384	8,798
Imports, general	13,991	5,178	2,744	3,709	3,882	2,737
Imports for consumption	13,511	3,525	2,123	4,030	3,060	3,148
Consumption	8,345	11,605	11,128	13,691	11,061	12,311
Stocks:						
Producer	[1] 2,109	2,402	2,667	3,004	3,313	580
Consumer and dealer	3,690	3,143	3,212	3,054	2,934	2,090
World: Production	66,335	68,714	73,568	69,761	61,481	61,767

W Withheld to avoid disclosing individual company confidential data.
[1] 1958–59 not included to avoid disclosing company confidential data.

LEGISLATION AND GOVERNMENT PROGRAMS

Revised tungsten stockpile objectives and new subobjectives deemed necessary for a 3-year conventional war were established by the Office of Emergency Planning (OEP). On April 3, 1964, a reduced objective of 44 million pounds of tungsten was announced and the following subobjectives were established.

	Pounds tungsten content
Ferrotungsten	1,800,000
Tungsten metal, powder, hydrogen reduced	1,600,000
Tungsten metal, powder, carbon reduced	500,000
Tungsten carbide, powder	2,000,000
Tungsten carbide, crystalline	1,100,000

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[1] Commodity specialist, Division of Minerals.

In April the General Services Administration (GSA) transferred 47,777 short-ton units of tungsten trioxide (757,839 pounds tungsten content) from the Defense Production Act (DPA) inventory to the Atomic Energy Commission (AEC) for Governmental use. A contract was subsequently issued to the General Electric Co., Cleveland, Ohio, to process this concentrate to tungsten powder for use by the Oak Ridge National Laboratory, Oak Ridge, Tenn.

TABLE 2.—Tungsten materials in Government inventories as of December 31, 1964

(Thousand pounds, tungsten content)

	National (strategic) stockpile	Defense Production Act (DPA) Inventory	Supplemental stockpile	Total
Tungsten, all forms:				
Stockpile grade	103, 787	52, 163	4, 479	160, 429
Nonstockpile grade	16, 228	25, 272	1, 295	42, 795
Tungsten carbide powder [1]	(886)	----	(1, 080)	(1, 966)
Ferrotungsten [1]	(1, 652)	----	----	(1, 652)
Tungsten metal powder:				
Hydrogen reduced [1]	(1, 092)	----	----	(1, 092)
Tungsten metal powder:				
Carbon reduced [1]	(499)	----	----	(499)

[1] Figures in parentheses are upgraded forms and are included in the figures for tungsten, all forms, stockpile grade.

Although no tungsten disposals were made during 1964, GSA announced plans early in 1965 for a long-term tungsten disposal program covering the orderly disposal of over 77 million pounds of surplus tungsten from the DPA inventory.

Revised instructions were issued by GSA in July covering new regulations for the storage of tungsten concentrates in the strategic (national) stockpile.

DOMESTIC PRODUCTION

Stimulated by the demand for tungsten as a replacement for molybdenum in steelmaking, the increased requirements for tungsten-rhenium alloys for use in nuclear reactors, and by the increased market price of tungsten concentrates, U.S. tungsten mine shipments increased 63 percent during 1964. Of the seven mines in six States which reported production during the year, only the Pine Creek mine of Union Carbide Nuclear Co., near Bishop, Calif., and the Climax mine of Climax Molybdenum Co., a division of American Metal Climax, Inc., near Leadville, Colo., were operated continuously. Both of these mines obtained tungsten as a coproduct or byproduct. At the Pine Creek mine, tungsten was the main metal recovered, along with minor amounts of molybdenum and copper. At the Climax mine, molybdenum was the main metal recovered, while tungsten was recovered as a byproduct. Intermittent tungsten production also was reported from Mohave County, Ariz., Lake County, Colo., Valley County, Idaho, Nye County, Nev., and Baker County, Oreg.

The equipment from the Hamme mine of the Tungsten Mining Corp., Vance County, N.C., was sold at auction and the mine, at which operations were suspended early in 1963, was left to fill with water.

TABLE 3.—Tungsten concentrate shipped from mines in the United States

Year	Quantity			Reported value, f.o.b. mines[1]		
	Short tons, 60 percent WO_3 basis	Short-ton units WO_3[2]	Tungsten content (thousand pounds)	Total (thousands)	Average per unit of WO_3	Average per pound of tungsten
1955–59 (average)	8,821	529,285	8,396	$25,744	$48.64	$3.07
1960	7,325	439,530	6,972	9,815	22.33	1.40
1961	8,245	494,741	7,847	10,565	21.36	1.35
1962	8,429	505,685	8,021	11,639	23.02	1.45
1963	5,657	339,402	5,384	7,202	21.22	1.34
1964	9,244	554,676	8,798	11,251	20.28	1.28

[1] Values apply to finished concentrate and are in some instances f.o.b. custom mill.
[2] A short-ton unit equals 20 pounds of tungsten trioxide (WO_3) and contains 15.862 pounds of tungsten.

CONSUMPTION AND USES

Tungsten carbides which continued to represent the major individual end use of tungsten accounted for 43 percent of the total consumption, cemented carbides for 34 percent, and other carbides (crystalline and cast) for 9 percent.

Metalonics Corp., a Boston-based subsidiary of Kawecki Chemical Co., began manufacturing small diameter tungsten tubing in commercial quantities for use in corrosion-resistant and high-temperature-strength applications.

Allied Chemical Corp. installed a 75,000 pound autoclave at its new Baton Rouge, La., facility to consolidate large tungsten shapes by pressure bonding high-purity tungsten beads produced by vapor reduction. This autoclave, designed to operate at pressures of 15,000 pounds per square inch (psi) and at temperatures of 3,000° F, was capable of producing shapes weighing 5,000 pounds each.

General Electric Co. planned to build a new $2 million chemical facility to process tungsten ore to ammonium paratungstate (APT) adjacent to its Cleveland wire plant and refractory metals plant. The new facility was expected to be completed and go on-stream late in 1965. The four-story 20,000 square foot plant will be the largest of its kind in the United States. In addition to new process innovations, the facility will include a $200,000 waste disposal system.

A new, highly automated plant for the production of flame-plated tungsten carbide coatings was planned by the Linde Division of Union Carbide Corp., at Charlotte, N.C., for completion in 1965. This plant, the fourth such domestic facility, will employ between 35 and 40 persons when operating at full production.

Cleveland Tungsten, Inc., a subsidiary of the Molybdenum Corporation of America, dedicated its new $1 million plant at Solon, Ohio, which was to have double the capacity of the existing plant in Cleveland. Construction of the plant and relocation of equipment and operations was to be completed during 1965.

A new fabricating service was established by the Metals Dept. of The Dow Chemical Co., Denver, Colo. The new unit, designated Precision Fabrication Services, began fabricating testing equipment and tungsten prototype components for the aerospace industry in the fall of 1964; full operation was expected by mid-1965. Initial emphasis was placed on the development of methods of machining to tolerances 5 to 10 times closer than usual.

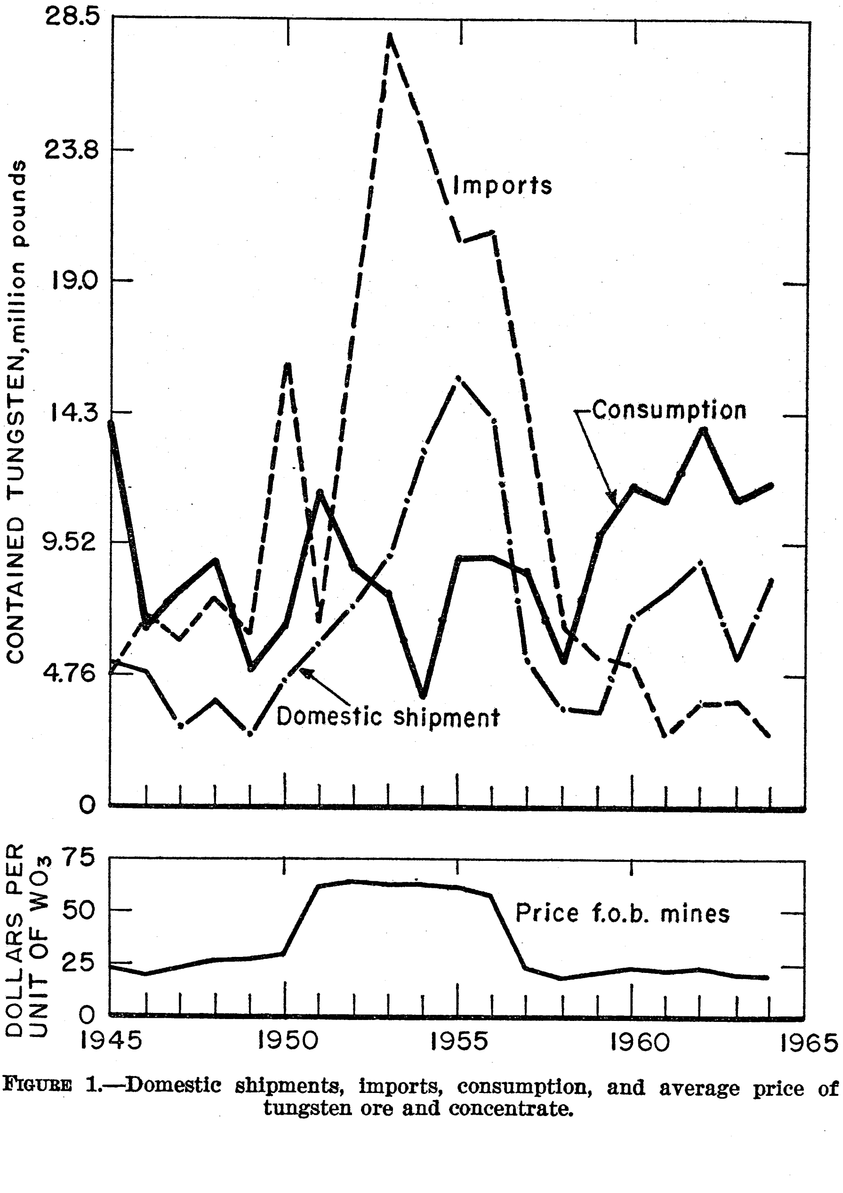

FIGURE 1.—Domestic shipments, imports, consumption, and average price of tungsten ore and concentrate.

TABLE 4.—Production, shipments, and stocks of tungsten products in the United States in 1964

(Thousand pounds of contained tungsten)

	Hydrogen and carbon-reduced metal powder	Tungsten carbide powder		Chemicals	Other [1]	Total
		Made from metal powder	Crushed cast			
1963:						
Received from other producers	3,160	4	----------	2,630	1,438	7,232
Gross production during year	5,952	2,334	986	8,726	2,145	20,143
Used to make other products listed here	3,136	----------	----------	6,605	835	10,576
Net production	2,816	2,334	986	2,121	1,310	9,567
Shipments [2]	6,079	2,419	933	4,245	2,785	16,461
Producer stocks, December 31, 1963	1,907	95	172	2,667	736	5,577
1964:						
Received from other producers	3,790	3	9	4,297	1,147	9,246
Gross production during year	7,411	3,233	1,381	8,751	2,313	23,089
Used to make other products listed here	4,433	----------	----------	7,556	918	12,907
Net production	2,978	3,233	1,381	1,195	1,395	10,182
Shipments [2]	6,405	3,183	1,434	6,544	2,322	19,888
Producer stocks, December 31, 1964	2,271	148	128	1,658	957	5,162

[1] Includes ferrotungsten, tungsten carbide powder (crystalline), scheelite (produced from scrap), nickel-tungsten, self-reducing oxide, pellets, and scrap.

[2] Includes quantities consumed by producing firms for manufacture of products not listed here.

TABLE 5.—Consumption of tungsten products by end uses, in 1964

(Thousand pounds of contained tungsten)

End Uses	Ferro-tungsten, melting base, self-reducing tungsten, tungsten sponge mix, etc.	Carbon reduced tungsten powder[1]	Hydrogen reduced tungsten powder[2]	Made from metal powder	Crystalline and crushed cast	Chemicals	Scheelite (natural or synthetic)	Scrap	Total
1963:									
Steel:									
High speed	611	45	--------	--------	--------	--------	1,084	129	1,869
Hot work and other tool	290	14	--------	--------	--------	--------	185	51	540
Alloy (other than tool)[3]	238	10	3	--------	--------	--------	130	74	455
High-temperature nonferrous alloys[4]	58	102	34	--------	--------	--------	173	195	562
Other nonferrous alloys[5]	13	7	132	5	233	224	3	124	741
Tungsten metal:									
Wire, rod, and sheet	--------	--------	1,276	--------	--------	--------	--------	------	1,276
Other[6]	--------	1	718	--------	--------	--------	--------	------	719
Carbides:									
Cemented or sintered	--------	--------	40	2,284	1,069	--------	--------	65	3,458
Other (including cast or fused)	3	61	38	19	599	--------	--------	32	752
Chemicals[7]	--------	--------	--------	--------	--------	144	--------	------	144
Total	1,213	240	2,241	2,308	1,901	368	1,575	670	10,516
Stocks at consumer plants Dec. 31, 1963	299	44	665	160	6	220	--------	204	1,598
1964:									
Steel:									
High speed	383	29	--------	--------	--------	--------	1,009	129	1,550
Hot work and other tool	105	17	--------	--------	--------	--------	363	7	492
Alloy (other than tool)[3]	351	12	2	--------	--------	--------	141	139	645
High temperature nonferrous alloys[4]	54	215	18	--------	--------	--------	174	180	641
Other nonferrous alloys[5]	16	5	136	4	240	65	3	101	570
Tungsten metal:									
Wire, rod, and sheet	--------	--------	1,455	--------	--------	7	--------	------	1,462
Other[6]	--------	2	733	--------	1	--------	--------	------	736
Carbides:									
Cemented or sintered	--------	--------	58	3,067	565	--------	--------	56	3,746
Other (including cast or fused)	4	66	74	18	870	--------	--------	27	1,059
Chemicals[7]	--------	--------	--------	--------	--------	151	--------	------	151
Total	913	346	2,476	3,089	1,676	223	1,690	639	11,052
Stocks at consumer plants Dec. 31, 1964	365	59	883	141	11	41	--------	221	1,721

[1] Includes tungsten metal pellets that may be hydrogen or carbon reduced or scrap.
[2] Does not include quantities consumed in making tungsten carbide powder.
[3] Includes steel mill rolls, stainless and other alloy steels.
[4] Includes cutting and wear resistant alloys, high-temperature and other superalloys.
[5] Includes diamond drill bit matrices, electrical contact points, alloy welding rods, and resistance alloys.
[6] Includes wire, rod, and sheet produced from arc-melted material and various shaped parts produced by powder metallurgy techniques.
[7] Includes fluorescent powders, organic and inorganic pigments.

PRICES AND SPECIFICATIONS

The price of domestic tungsten concentrate, quoted in E&MJ Metal and Mineral Markets from January through early July, ranged from \$16 to \$18 per short-ton unit of tungsten trioxide (WO_3), f.o.b. mine or mill. On July 13, the quoted price rose to \$17 to \$19 where it remained throughout the remainder of the year. The average domestic price of ammonium paratungstate (APT) during 1964 was about \$23 per short-ton unit.

Carbon-reduced tungsten metal powder (99.8 percent in 1,000-pound lots) continued to be quoted at the 1962–63 price of $2.75 per pound in E&MJ Metal and Mineral Markets. The quoted price of hydrogen-reduced tungsten metal powder (99.99 percent) ranged from $2.45 to $3.20 per pound during the first part of the year. Because of the increased cost of tungsten concentrate, the price of hydrogen-reduced tungsten powder was raised to $2.70 to $3.50 in late May and to $2.85 to $3.63 in mid-December. During 1964 the domestic price of ferrotungsten continued to be quoted at $1.75 per pound of contained tungsten (in lots of 5,000 pounds or more, ¼-inch lump, packed, f.o.b. destination, continental United States, 70 to 80 percent tungsten). Imported ferrotungsten was quoted at $1.50 per pound during the year.

TABLE 6.—Monthly prices of tungsten concentrate in 1964

Month	Foreign ore per short-ton unit of WO_3, 65-percent basis, c.i.f. U.S. ports, duty extra			London market, shillings per long-ton unit of WO_3	
	Wolfram and Scheelite				
	Low	High	Average [1]	Low	High
January	$13.25	$14.00	$13.57	107s	120s
February	12.00	14.00	12.88	96½s	116s
March	11.00	12.50	11.75	82½s	100s
April	11.00	11.75	11.31	80s	95s
May	11.25	14.25	12.62	92½s	114s
June	14.25	14.75	14.50	112½s	119s
July	13.50	15.50	14.38	105s	128½s
August	12.50	13.25	12.80	100s	107½s
September	13.25	15.75	14.75	105s	130s
October	15.25	16.75	15.88	117½s	135s
November	16.25	18.75	17.75	131s	167½s
December	18.75	21.50	20.38	169s	215s
Average price			14.38		
Duty			7.93		
Average price, duty paid			22.31		

[1] Arithmetic average of weekly quotations.

Source: E&MJ Metal and Mineral Markets.

FOREIGN TRADE

Imports.—General imports of tungsten concentrate decreased 30 percent; 95 percent of the total came from Bolivia (37 percent), Portugal (16 percent), Peru (16 percent), the Republic of Korea (16 percent), Argentina (6 percent), and Australia (4 percent). Five percent came from four other countries. Imports for consumption of tungsten concentrate increased 3 percent. There were no imports of tungsten ore and concentrate duty-free for the U.S. Government.

Imports of ferrotungsten and ferrosilicon-tungsten during 1964 totaled 311,274 pounds, tungsten content, valued at $301,132, from Austria (80 percent), Portugal (12 percent), and France (8 percent).

During 1964, imports of tungsten or tungsten carbide in lumps, grains, or powder contained 59,675 pounds of tungsten valued at $122,200 compared with 147,811 pounds valued at $273,781 reported in 1963.

Exports.—Exports of tungsten concentrate were 153,748 pounds, gross weight, valued at $144,874. Exports of ferrotungsten totaled 880 pounds, gross weight, valued at $2,068.

Exports of tungsten metal powder totaled 223,008 pounds valued at $1,235,313. Exports of tungsten metal and alloys in crude form and scrap were 453,579 pounds valued at $345,421. Exports of semifabricated tungsten forms were 58,196 pounds valued at $1,125,742.

TABLE 7.—U.S. imports for consumption of tungsten ore and concentrate, by countries

(Thousand pounds and thousand dollars)

Country	1963			1964		
	Gross weight	Tungsten content	Value	Gross weight	Tungsten content	Value
Argentina	716	398	$134	327	165	$65
Australia	326	185	98	198	115	53
Bolivia	1,697	942	437	2,132	1,173	751
Burma	149	85	78			
Burundi and Rwanda				43	23	23
Canada	162	96	59	71	38	29
Colombia				62	36	60
Germany, West	(1)	(1)	(1)			
Hong Kong				34	18	14
Japan	69	38	17			
Korea, South	1,542	846	478	962	612	324
Peru	59	35	17	873	501	386
Portugal	739	435	261	728	435	278
United Kingdom				56	32	25
Total	5,459	3,060	1,579	5,486	3,148	2,008

[1] Less than ½ unit.

Source: Bureau of the Census.

TABLE 8.—U.S. imports for consumption of ferrotungsten, by countries

(Thousand pounds and thousand dollars)

Country	1963			1964		
	Gross weight	Tungsten content	Value	Gross weight	Tungsten content	Value
Australia	33	26	$17			
Austria	421	338	228	111	89	$56
Brazil				11	9	8
France	250	202	150	60	48	35
Germany, West	207	166	108	33	27	16
Portugal	55	46	33	22	18	17
Sweden	127	104	73	5	4	4
Total	1,093	882	609	242	195	136

Source: Bureau of the Census.

TABLE 9.—U.S. imports for consumption of tungsten or tungsten carbide forms

Year	Ingots, shot, bars, and scrap		Wire, sheets, or other forms, n.s.p.f.[1]		Total	
	Pounds	Value	Pounds	Value	Pounds	Value
1955–59 (average)	243,516	$384,182	169,987	$417,510	413,503	$801,692
1960	170,383	207,217	174,877	528,035	345,260	735,252
1961	131,117	164,460	93,199	551,473	224,316	715,933
1962	194,111	188,668	73,448	383,670	267,559	572,338
1963	363,656	217,892	[r] 158,175	[r] 461,135	[r] 521,831	[r] 679,027
1964	322,826	181,214	74,734	213,302	397,560	394,516

[r] Revised.

[1] Not specifically provided for.

Source: Bureau of the Census.

WORLD REVIEW

A fourth meeting of the United Nations Ad Hoc Committee on Tungsten was held in New York City to assess and evaluate the current tungsten situation and to consider methods for stabilizing tungsten market conditions. Items considered at this meeting included the establishment of an International Tungsten Institute and a proposal by five producing countries to establish a form of quota system between member governments regarding the purchase of tungsten concentrate. The Ad Hoc Committee decided to expand the Technical Working Group from four to eight members and to rename it the Working Group.

The Working Group, consisting of representatives of Australia, Austria, Bolivia, Portugal, the Republic of Korea, Sweden, the United States, and West Germany, met in New York in January 1965 to prepare a report for the fifth meeting of the U.N. Ad Hoc Committee on Tungsten which was tentatively scheduled to meet in April or May in New York City.

TABLE 10.—World production of tungsten ore and concentrate, by countries[1]

(Short tons, 60% WO_3 basis)

Country	1955-59 (average)	1960	1961	1962	1963	1964 [p]
North America:						
Canada	1,138	----	----	3	----	----
Mexico	340	203	193	88	36	9
United States (shipments)	8,821	7,325	8,245	8,429	5,657	9,244
Total	10,299	7,528	8,438	8,520	5,693	9,253
South America:						
Argentina	1,167	893	892	635	159	73
Bolivia (exports)	4,225	2,370	3,104	2,798	2,513	2,285
Brazil	2,126	1,867	1,361	1,368	612	[e] 110
Peru	977	538	428	435	572	743
Total	8,495	5,668	5,785	5,236	3,856	3,211
Europe:						
Austria	[2] 146	243	317	320	246	116
Finland	85	----	58	----	----	----
France	1,214	753	806	757	772	----
Itlay	19	8	3	1	2	1
Portugal	3,995	3,215	3,274	2,754	1,784	1,948
Spain	1,312	1,030	1,192	777	162	35
Sweden	500	311	345	295	380	----
U.S.S.R. [e]	8,900	10,500	11,000	11,600	12,100	12,100
United Kingdom	41	----	----	----	----	----
Yugoslavia	86	86	9	57	19	[e] 18
Total [e]	16,300	16,100	17,000	16,600	15,500	14,200
Asia:						
Burma [3]	1,653	1,041	1,102	882	827	529
China [e]	19,000	24,900	24,900	24,900	24,900	22,500
Hong Kong	39	39	20	18	9	1
India	1	3	11	12	6	10
Japan	1,081	1,082	1,033	1,160	856	951
Korea:						
North [e]	2,925	5,500	5,500	4,400	4,400	4,400
South	4,085	6,321	8,107	8,219	6,092	6,600
Malaysia	79	46	41	11	8	6
Thailand	1,027	487	568	471	228	474
Total [e]	29,900	39,400	41,300	40,100	37,300	35,500
Africa:						
Congo, Republic of the (Léopoldville) [3]	1,065	634	595	406	223	[e] 550
Rhodesia (formerly Southern)	170	11	55	24	3	----
Rwanda	631	504	734	165	14	53
South Africa, Republic of	285	37	30	28	9	4
South-West Africa [3]	203	154	190	171	239	216
Uganda (exports)	130	84	243	105	----	----
United Arab Republic (Egypt)	4	----	91	----	----	----
Total	2,488	1,424	1,938	899	488	823
Oceania:						
Australia	2,230	2,075	2,866	1,946	1,793	1,860
New Zealand	24	10	6	10	6	6
Total	2,254	2,085	2,872	1,956	1,799	1,866
World total (estimate)	69,700	72,200	77,300	73,300	64,600	64,900

[e] Estimate. [p] Preliminary.

[1] This table incorporates some revisions. Data do not add exactly to totals shown because of rounding where estimated figures are included in the detail.

[2] Average annual production 1957-59.

[3] Including WO_3 in tin-tungsten concentrates.

NORTH AMERICA

Canada.—Canada Tungsten Mining Corp., Ltd., reopened its Flat River scheelite mine in the Northwest Territories in October and at the yearend was the only Canadian tungsten producer. The mine, which had been closed in mid-1963 due to the low price of tungsten, was estimated to have a 10-year ore supply assuming that the modernized mill was operated continuously at its maximum capacity of 300 tons per day.[2]

Burnt Hill Tungsten & Metallurgical Ltd. explored its property north of Frederickton, New Brunswick. Nineteen holes drilled to a depth of over 500 feet indicated three and possibly five veins containing tungsten with minor amounts of tin and molybdenum. The ore appears to be in zones from 14 to 50 feet wide and to contain 0.75 to 1.00 percent WO_3, with about 2 pounds per ton each of molybdenum and tin.[3]

The Marco Division of Kennametal, Inc., Port Coquitlam, British Columbia, continued to produce tungsten carbide powder and other tungsten products from imported ores and concentrates.

SOUTH AMERICA

Argentina.—A surcharge of 200 percent was imposed upon tungsten imports.[4] This levy was established to restrict imports and promote the use of domestic rather than foreign ores by the country's five tungsten consumers.

Bolivia.—Some tungsten was produced as a byproduct of tin mining operations at the Unificanda and Caracoles mines, but most production was from the Bolsa Negra mine worked solely for tungsten.

Peru.—The Cerro de Pasco Corp. announced plans to install an additional circuit at its Morococha lead-zinc mill to recover tungsten concentrate which previously had been discharged in the tailings.[5]

EUROPE

Austria.—Metallwerk-Plansee, Reutte, Austria, which produced large, high-purity tungsten and tungsten alloy sheet in widths up to 40 inches, continued to be the only consumer of tungsten concentrates.

Portugal.—Although there were 11 operating producers of tungsten ores and concentrates, the major producer, Beralt Tin and Wolfram, Ltd., which recovered tungsten as a coproduct of tin mining operations, accounted for approximately 76 percent of the total production. There continued to be only two Portuguese consumers of tungsten concentrates.

Sweden.—Tungsten mining was halted at the end of 1963 and no production was reported during 1964. Approximately 75 percent of the tungsten used by Sweden's 10 consumers was in the form of tungsten carbide for use in wear-resistant and abrasion-resistant applications such as hard facing, drill bits, metal cutting tools, and metal forming dies. The remaining 25 percent was consumed by the steel industry in the form of ferrotungsten.

U.S.S.R.—A wide range of byproduct metals including tungsten, molybdenum and cobalt were recovered from lead and zinc concentrates at the oldest Soviet Union base metals smelter in the north Caucasus city of Ordzhonikidze. Plans were being made to reprocess large slag stockpiles which contain metals not recovered by former technology.[6]

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[2] Northern Miner (Toronto). Canada Tungsten Starts Up Again. V. 50, No. 38, Dec. 10, 1964, pp. 1, 8.

[3] Canadian Mining Journal. Burnt Hill Tungsten & Metallurgical. V. 85, No. 10, October 1964, p. 16.

[4] Metal Bulletin (London). Argentine Tungsten Levy. No. 4869, Feb. 4, 1964, p. 19.

[5] Bureau of Mines. Mineral Trade Notes. V. 59, No. 1, July 1964, p. 24.

The largest and most modern facilities for the recovery of tungsten in the U.S.S.R. was at Tyrny-Auz and Nal'chik in the northern Caucasus. Ore from the mines of the Tyrny-Auz deposit were carried by cableway to a concentrating plant. The concentrate was shipped to a hydrometallurgical plant at Nal'chik where the tungsten and molybdenum were separated. This plant, which began operation in 1962, is believed to be highly automated.

United Kingdom.—In late September the British Board of Trade announced that it would resume sales of tungsten ore from the UK stockpile. Sales were conducted through the Board's agent, British Tungsten, Ltd. It was expected that the disposal of this material would be conducted at a rate of about 200 tons per month.

ASIA

China.—Although little information is available on the tungsten industry of mainland China, statistical data compiled by the United Nations Ad Hoc Committee on Tungsten indicated that some tungsten which probably originated from mainland China was exported to western European countries through other satellite countries.[7] Final 1964 import statistics from the United Kingdom indicated that 150 tons of tungsten ore were obtained from Hungary and 80 tons were obtained from Czechoslovakia.[8] However, because there were no known tungsten mining operations in these countries this material is believed to represent transhipments which originated from mainland China.

Korea, South.—The Korea Tungsten Mining Co. continued to be the largest of the three tungsten producers in South Korea. During the year a trade agreement was signed with India which specified that South Korea would sell zinc and lead metal and tungsten concentrates to India in return for various chemicals and Indian ferromanganese.

A comprehensive report described the tungsten and molybdenum mines, deposits, and resources of Korea.[9]

Thailand.—Of 81 tungsten ore producers, all except two obtained tungsten as a byproduct or coproduct of tin mining operations. The estimated capacity of the majority of these tungsten producers was believed to be less than 3 tons per month of concentrate.

The tungsten producing regions of southern Thailand in order of importance, were Nakhon Sithammarat, Ranong, Songkhla, Takuapa, and Phuket.

The Government sought to improve the efficiency of tin and tungsten mining operations through the establishment of Mineral Development Centers at Yala and Phuket. West Germany was believed to be prepared to assist in the establishment of a Vocational Mining School to be incorporated as a new department of the Technical Institute at Songkhla.

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[6] Engineering and Mining Journal. V. 165, No. 11, November 1964, pp. 158, 162.

[7] United Nations Conference on Trade and Development. Report of the United Nations Ad Hoc Committee on Tungsten on its Fourth Session (11–14 May 1965). TD/TUNGSTEN/COM/13, 14 May 1965, 79 pp.

[8] Metal Bulletin (London). U.K. Tungsten Ore Imports. No. 4975, Feb. 23, 1965, p. 26.

[9] Gallagher, David. Mineral Resources of Korea, Tungsten and Molybdenum, v. 5. Issued by Mining Branch, Industry and Mining Div., USOM/Korea, in cooperation with Geol. Survey, Republic of Korea, 1963, 81 pp.

OCEANIA

Australia.—Of the three tungsten producers, one mined scheelite (King Island Scheelite) and two mined wolfram ores. One wolfram mine was operated predominantly for tungsten with a minor amount of byproduct tin. The other produced wolfram as a coproduct of tin. Only one company, a steel producer, was a tungsten consumer.

Aberfoyle Tin, N.L., the Tasmanian tin-wolfram producer, produced less of both metals during the year ending June 30, due to a decrease in the grade of ore recovered. Monthly mine production was about 55 tons of tin concentrate and 10 to 12 tons of wolfram concentrate.

Metals Exploration, N.L., announced that underground development of the Leisner Mine at Wolfram Camp, Queensland, continued to disclose ore estimated to contain 3.5 percent molybdenite and 5.3 percent tungsten plus bismuth. Wolfram Camp is 80 miles inland from Cairns on the Yorke Peninsula. Freeport Sulphur Co. of New York planned to acquire 27-percent equity interest in Metals Exploration and supply technical support to allow expanded exploration and development.

Storeys Creek Tin Mining Co., a wholly owned subsidiary of North Australian Uranium Corp., N.L., produced 107 tons of tin metal in concentrates and 207 tons of tungsten oxide in concentrates from its mine in northeastern Tasmania during the year ending June 30.

TECHNOLOGY

The thermodynamic properties of lead tungstate and tungsten chloride were investigated by the Bureau of Mines.[10] Heat capacity and entropy of lead tungstate were determined and combined with other data to obtain the entropy of formation of the compound from its constitutent elements and oxides. The vapor pressure of tungsten chloride was determined using a metal diaphragm technique.

A new analytical technique for determining trace metals in high-purity tungsten was developed.[11]

A flexible flotation method for beneficiating and upgrading low-grade tactite-type tungsten ores produces a concentrate suitable for chemical processing into high-quality synthetic scheelite.[12]

Electrolytic deposition at 1,000° C in an electrolyte containing seven parts sodium pyrophosphate, two parts sodium chloride, and one part sodium tetraborate yielded tungsten metal of 99.9 percent purity from scheelite concentrates containing from 25 to 73 percent WO_3 as feed material.[13]

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[10] Stevenson, F. D., C. E. Wicks, and F. E. Block. Vapor Pressure of Tungsten (VI) Chloride and Hafnium (IV) Iodide by a Metal Diaphragm Technique. BuMines Rept. of Inv. 6367, 1964, 32 pp.

Weller, W. W., and K. K. Kelley. Low-Temperature Heat Capacities and Entropies at 298.15° K of Lead Molybdate and Lead Tungstate. BuMines Rept. of Inv. 6357, 1964, 5 pp.

[11] Spano, E. F., T. E. Green, and W. J. Campbell. Evaluation of a Combined-Ion Exchange X-Ray Spectrographic Method for Determining Trace Metals in Tungsten. BuMines Rept. of Inv. 6565, 1964, 16 pp.

[12] Dean, K. C., and C. H. Schack. Flotation of Calcerous Scheelite Ores. BuMines Rept. of Inv. 6385, 1964, 15 pp.

A report describing a study on the electrodeposition of protective coatings of tungsten from a sodium and lithium borate-tungstate-tungstic oxide fused salt electrolyte generated considerable public interest.[14] Thick, smooth adherant coatings of tungsten were successfully electrodeposited on molybdenum, stainless steel, Inconel, and nickel. The best coatings were obtained at 900° C, at a current density of 0.3 to 0.4 ampere per square inch, when the electrolyte was stirred by rotation of the cathode.

The Bureau of Mines continued its studies of tungsten vapor deposition and released another report describing this research.[15] Experiments showed that nozzles of graphite and rhenium-coated graphite could be successfully lined with a thin, uniform coating of tungsten by reduction-deposition of tungsten hexafluoride vapor.

At the Oak Ridge National Laboratory (ORNL) similar but independent studies were made of vapor deposition for the Atomic Energy Commission (AEC) in the hope of developing a one-step conversion process for forming the fuel core by vapor deposition of uranium from uranium hexafluoride, and then covering the core with an integral vapor deposited cladding of tungsten.[16] ORNL is evaluating this method of forming and cladding fuel elements in an attempt to omit the high temperatures and complex fabrication equipment presently required to fabricate fuel elements and their refractory metal coatings. ORNL is also studying the production of tungsten-25 percent rhenium alloys, for use as reactor structural materials, by codepositing these metals from their halide vapors.

A report describing the apparatus and procedures used by the Bureau of Mines for extracting tungsten chloride from complex ores and concentrates by chlorination was issued.[17] The pretreatment of ores with chlorine in the presence of a reducing agent to convert metal oxides to chlorine salts and the selective volatilization and condensation of chlorine salts were discussed.

A new reduction technique was developed by Bureau metallurgists to obtain high-purity tungsten and molybdenum from various feed materials by electrowinning the metals from fused-salt solutions.[18] The tungsten content of the electrolyte varied from 5 to 60 percent, optimum operating temperature of the bath was 1,000° C. Experimental results indicated that the current density during tungsten electrowinning was not a critical factor and could vary from 5 to 300 amps per square decimeter (100 square centimeters) without noticeable change in the efficiency.

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[13] Gomes, J. M., J. B. Zadra, and Don H. Baker, Jr. Electrolytic Extraction of Tungsten from Western Scheelite. BuMines Rept. of Inv. 6512, 1964, 13 pp.

[14] McCawley, F. X., C. B. Kenahan, and David Schlain. Preparation of Thick Coatings of Tungsten. BuMines Rept. of Inv. 6454, 1964, 28 pp.

[15] Hoertel, F. W. Vapor Deposition of Tungsten on MERM Rocket Nozzles. BuMines Rept. of Inv. 6464, 1964, 19 pp.

[16] U.S. Atomic Energy Commission. Metal and Ceramics Division, Annual Report for Period Ending 30 June 1964. U.S. Dept. of Commerce, Clearinghouse for Federal Scientific and Technical Information, ORNL–3670, November 1964, 317 pp.

[17] Henderson, A. W. Chlorination of Ores and Concentrates. J. Metals, v. 16, No. 2, February 1964, pp. 155–160.

[18] Baker, Don H., Jr. Electrowinning Molybdenum and Tungsten. J. Metals, v. 16, No. 11, November 1964, pp. 873–876.

Continued industrial interest was expressed in the production of high-purity molybdenum and tungsten by the fused-salt electrolytic process pioneered by the Bureau of Mines. Four reports covering this work have been released.[19]

Because of its excellent high-temperature, high-strength properties, and room temperature ductility, investigations were conducted for the AEC on the tungsten-25 percent rhenium (W–25Re) alloy. These investigations are described in the Rhenium section of the Minor Metals and Minerals chapter in this yearbook.

A new method of consolidating tungsten and tungsten alloy powders had been developed which uses the magnetic pinch effect originally developed for thermonuclear research.[20] This pinch is capable of exerting pressures in excess of 25 tons per square inch, enough to produce a dense compact which is strong enough for easy handling. Although this method is not suitable for production-scale use, knowledge of the process may lead to the development of new magnetic forming techniques.

A gamma shielding material composed primarily of powdered tungsten and having a shielding efficiency nearly as high as that of solid lead has been introduced.[21] The material is a dry powder which, when mixed with water at the point of use, can be poured, sprayed, cast, or plastered and is self-supporting, easily bonded to most structural materials, and is amenable to sawing, drilling, and tapping.

A filled-billet extrusion technique suitable for producing seamless tungsten tubing directly from metal powder was developed which eliminated the need for a consolidation step.[22]

A new method of cold extrusion of refractory metals was developed during studies of nuclear fuel fabrication technology.[23] Mixtures of tungsten powder and an organic binder were successfully extruded at room temperature by this technique into rods having hexagonal cross sections and containing seven longitudinal holes for fuel loading.

The resistance of refractory metals to corrosion by liquid lithium at temperatures ranging from 2,000° to 3,000° F was evaluated.[24] Under these conditions tungsten metal was rated excellent, molybdenum metal was rated good, the Ta–10W alloy was rated fair, while chromium metal was rated poor.

Eleven refractory metals and alloys were selected for corrosion studies in molten lithium (2,500°–3,000° F) and cesium (2,500°–3,400° F) and for compatability studies with nuclear reactor fuels (UN, UC, and UO_2) at 2,500° to 3,400° F.[25] Of the specimens exposed to lithium at 2,800° to 3,000° F for 100 hours, tungsten, W-0.9Cb, W-15Mo, W-25Re, and TZM were found to be compatible. These same alloys were compatible with molten cesium after 1,000 hours of exposure at 2,500° to 3,100° F.

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[19] Cattoir, F. R. Experiments in Fused-Salt Electrolysis of Tungsten. BuMines Rept. of Inv. 6154, 1963, 10 pp.

Zadra, J. B., and J. M. Gomes. Electrowinning Tungsten and Associated Molybdenum from Scheelite. BuMines Rept. of Inv. 5554, 1959, 23 pp.

Work cited in footnote 13.

Work cited in footnote 18.

[20] Product Engineering. A Brand-new Way to Fabricate Powdered Metal Parts. V. 35, No. 17, Aug. 17, 1964, pp. 45–46.

[21] Chemical Engineering. Metallic Mortars Bond Easily. V. 71, No. 23, Nov. 9, 1964, p. 88.

[22] Iron Age. Extrusions Form Tungsten Tubes. V. 193, No. 3, Jan. 16, 1964, pp. 78–79.

[23] Steel. Refractory Metals Cold Extruded. V. 155, No. 9, Aug. 31, 1964, pp. 29–30.

[24] Bartlett, E. S., and H. R. Ogden. Summary of the Eighth Meeting of the Refractory Composites Working Group. Battelle Memorial Inst., Columbus, Ohio, DMIC Memorandum 192, Apr. 20, 1964, 15 pp.

[25] DeMastry, J. A., N. M. Griesenauer, and F. A. Rough. Investigation of High Temperature Refractory Metals and Alloys for Thermionic Converters. Defense Documentation Center AD 442960, Washington, D.C., July 10, 1964, 20 pp.

Because of the refractory nature of tungsten and its proposed usage at elevated temperatures, research was conducted on the development and evaluation of coatings and alloying additions to improve the oxidation resistance.[26]

A comprehensive report summarized data on specific silicide- and aluminide-type coatings for tungsten and tungsten-base alloys.[27]

Eight metalworking procedures were evaluated for application to refractory metals.[28] A special report on explosive forming of metals was also issued.[29] Studies indicated that both arc-cast and swaged tungsten billets could be extruded by the high-energy-rate method using a horizontal Dynapak machine.[30] Small diameter rods up to 16 inches long were successfully extruded in air at 3,000° to 3,500° F.

Successful extrusion of arc-cast tungsten-columbium and tungsten-molybdenum-columbium alloy billets under a variety of conditions was achieved.[31] At higher extrusion temperatures, molybdenum jacketing was found to be more advantageous than glass lubricants.

Fabrication techniques were developed to produce high-performance porous tungsten ion emitters for ion-propulsion systems.[32] Through carefully controlled, near-isostatic compaction of closely sized spherical tungsten powder, compacts having adequate green strengths were made at room temperature.

A process has been developed for producing high-purity porous, foamed tungsten with a density as low as 0.475 gram per cubic centimeter (2.5 percent of the density of solid tungsten).[33] The material is currently being evaluated for use in transpiration cooled rocket nozzles, light, high-temperature sandwich structures, thermionic emitters, vacuum furnace setter plates, and specimen holders.

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[26] Bartlett, R. W. Tungsten and Molybdenum Oxidation Kinetics at Extremely High Temperatures. Philco Corp., Newport Beach, Calif., ML-TDR-64-290 (U.S. Air Force Contract No. AF 33(657)-8654), September 1964, 61 pp.

Bartlett, R. W., and P. R. Gage. Investigation of Mechanisms for Oxidation Protection and Failure of Intermetallic Coatings for Refractory Metals. Philco Corp., Newport Beach, Calif., ASD-TDR-63-753, pt. II (U.S. Air Force Contract No. AF 33(657)-9170), July 1964, 127 pp.

Battles, J. E., R. Speiser, and G. R. St. Pierre. The Stability of Tungsten in Carburizing and Oxidizing Atmospheres. Ohio State University, Columbus, Ohio, ML-TDR-64-272 (U.S. Air Force Contract No. AF 33(616)-8005), August 1964, 41 pp.

Nolting, H. J., and R. A. Jefferys. Oxidation Resistant High Temperature Protective Coatings for Tungsten. Thompson Ramo Wooldridge Inc., Cleveland, Ohio, ML-TDR-64-227 (U.S. Air Force Contract No. AF 33(657)-11151), July 1964, 112 pp.

[27] Giveaut, W. A., and E. S. Bartlett. Properties of Coated Refractory Metals. Battelle Memorial Inst., Columbus, Ohio, DMIC Report 195, Jan. 10, 1964, 92 pp.

[28] Boulger, F. W., W. M. Baldwin, Jr., A. H. Clauer, J. A. Houck, M. J. Klein, H. R. Ogden, C. N. Reid, A. R. Rosenfield, A. M. Sakroff, and D. E. Strohecker. Metal Deformation Processing, v. 1. Battelle Memorial Inst., Columbus, Ohio, DMIC Report 208, Aug. 14, 1964, 127 pp.

[29] Strohecker, D. E., R. J. Carlson, S. W. Porembka, Jr., and F. W. Boulger. Explosive Forming of Metals. Battelle Memorial Inst., Columbus, Ohio, DMIC Report 203, May 8, 1964, 59 pp.

[30] Holden, F. C., and F. W. Boulger. Second Status Report of the U.S. Government Metalworking Process and Equipment Program. Battelle Memorial Inst., Columbus, Ohio, DMIC Report 209, Nov. 23, 1964, 41 pp.

[31] Barth, V. D. Tungsten and Tungsten-Base Alloys. Defense Metals Inf. Center, Battelle Memorial Inst., Columbus, Ohio, DMIC Review of Recent Developments, May 15, 1964, 4 pp.

[32] Barth, V. D. Tungsten and Tungsten-Base Alloys. Defense Metals Inf. Center, Battelle Memorial Inst., Columbus, Ohio, DMIC Review of Recent Developments, Oct. 30, 1964, 4 pp.

[33] Missiles and Rockets. Firm Exploring Uses for Foamed Tungsten. V. 14, No. 18, May 4, 1964, p. 35.

An investigation of materials for use as extrusion containers indicated that metal-reinforced ceramics were suitable for this application at very high temperatures.[34] The materials examined were Al_2O_3, MgO, ZrO_2, and SiO_2 reinforced with 2-mil diameter molybdenum, and TiC, TaC, ZrC, VC, and CbC reinforced with 5-mil tungsten wire. TiC reinforced by 18 to 22 volume percent tungsten withstood billet temperature of 2,000° F.

Notch impact studies have shown that fully recrystallized tungsten fractures predominantly by simple cleavage at temperatures as high as 700° C rather than intergranularly as had been previously assumed.[35]

Starting with pressure-sintered tungsten, chromium, and carbon powders, the constitution of the tungsten-chromium-carbon system was determined at a homogenization temperature of 1,350° C.[36] The characteristic constituent of this system is the mixed phase $(W,Cr)_2C$.

Hexamine, a common, low-cost pharmaceutical often used as a diuretic, is being used as a reducing agent instead of hydrogen or carbon to produce tungsten metal powder from tungsten oxide.[37] Using hexamine as the reductant, less power is consumed per weight of metal produced, the equipment is subjected to less wear, and less maintenance is required than when standard reducing agents are used.

Cutting tools can now be easily surfaced with uniform films of tungsten carbide at low cost by unskilled operators.[38] The coatings consist of many tiny welds which, because they form true bonds with the base metal, will not chip or spall.

Small amounts of oxygen and carbon increase the ductile to brittle transition temperature of polycrystalline tungsten.[39] Oxygen lowers the ultimate and yield strength of polycrystalline tungsten but has no effect on single crystals. Carbon additions have no effect upon the ultimate strength but increase the yield strength of tungsten.

Work conducted on the consolidation, extrusion, and rolling of unalloyed tungsten was continued.[40] Arc-melted and extruded tungsten was successfully forged into thin-wall configurations by a process which could be scaled up to large-scale production operations.

The coarse grain cast structure of tungsten—15 percent molybdenum alloy rocket nozzles was found to be more resistant to thermal stress crack propagation than the fine grain structures which result from the recrystallization of extruded material.[41] The large grains characteristic of a cast structure deform plastically and terminate the advancing crack while the finer grain material have sufficient grain boundaries located in the general direction of crack propagation to permit cracks to propagate more easily.

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[34] Wagner, H. J. Fiber-Reinforced Metals. Defense Metals Inf. Center, Battelle Memorial Inst., Columbus, Ohio, DMIC Review of Recent Developments, Dec. 11, 1964, 2 pp.

[35] Page 2 of work cited in footnote 32.

[36] Page 3 of work cited in footnote 32.

[37] Ruth, John P. Cost of Making Tungsten Powders Lowered, Says M and R Research. American Metal Market, v. 71, No. 36, Feb. 21, 1964, pp. 1, 16.

[38] Iron Age. Electrode Coats Tools with Hard Carbide. V. 193, No. 4, Jan. 23, 1964, p. 56.

[39] Steel. Oxygen, Carbon Affect Tungsten. V. 155, No. 3, July 20, 1964, p. 18.

[40] Redlinger, R. W. Tungsten Forging Development Program. Defense Documentation Center AD 431588, Washington, D.C., January 1964, 34 pp.
Schoenfeld, W. J. Tungsten Sheet Rolling Program. Defense Documentation Center AD 431274, Washington, D.C., February 1964, 4 pp.

[41] Batchelor, J. D., and E. L. Olcott. Tungsten Alloys For Rocket Nozzles. Defense Documentation Center AD 430757, Washington, D.C., February 1964, 19 pp.

The effects of hydrogen and vacuum sintering treatments on the physical and mechanical properties of arc plasma-sprayed tungsten were studied at temperature ranges from 3,000° to 4,000° F in vacuum and 2,000° to 3,000° F in hydrogen for both single and duplex sintering cycles.[42] When a long time hydrogen treatment at 2,000° F preceded sinstering in vacuum at 4,000° F for 4 hours densities of 92 percent of theoretical and the highest values for modulus of rupture and bend-angle were obtained.

Interest in methods of extracting, consolidating, alloying, and utilizing tungsten were reflected by some of the patents issued in 1964.[43]

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[42] Spitzig, W. A., and G. W. Form. Effects of Sintering on the Physical and Mechanical Properties of Arc Plasma-Sprayed Tungsten. AIME Met. Soc. Trans., v. 230, No. 1, February 1964, pp. 67–70.

[43] Birdwell, Harold C., and David S. Rowley (assigned to Jersey Production Research Co., Tulsa, Okla.). Hard Surfacing Material. U.S. Pat. 3,128,165, Apr. 7, 1964.

Crooks, Donald D., and Robert E. Wallace (assigned to the U.S. Navy). Simultaneous Brazing and Corrosion Protecting Refractory Metals. U.S. Pat. 3,132,928, May 12, 1964.

France, Leonard L., and Robert L. Ammon (assigned to Westinghouse Electric Corp., East Pittsburgh, Pa.). Method of Sintering Tungsten. U.S. Pat. 3,140,944, July 14, 1964.

Hunt, James G. (assigned to the U.S. Atomic Energy Commission). Tungsten Tubing Extrusion Billet. U.S. Pat. 3,150,936, Sept. 29, 1964.

Laferty, John M. (assigned to Sylvania Electric Products Inc., Towanda, Pa.). Adding Sodium and Phosphorus to a Tungsten Oxide Reduction Process to Get Large Particle Sizes. U.S. Pat. 3.153,585, Oct. 20, 1964.

Pacala, Theodore, Richard H. Singleton, and James E. Twyman (assigned to General Motors Corp., Detroit, Mich.). Method of Forming Tungsten Shapes From Sprayed Metal Preforms and the Articles Resulting Therefrom. U.S. Pat. 3,146,134, Aug. 25, 1964.

Richardson, Lee S., Allen I. Lewis, and Leonard L. France (assigned to Westinghouse Electric Corp., East Pittsburgh, Pa.). Tungsten-Rhenium-Tantalum Alloys. U.S. Pat. 3,160,501, Dec. 8, 1964.

Saunders, Neal T. (assigned to the National Aeronautics and Space Administration). Method for Producing Porous Tungsten Ionizers for Ion Rocket Engines. U.S. Pat. 3,141,769, July 21, 1964.

Weisert, Edward D., Roger A. Perkins, and Doyle Geiselman (assigned to Union Carbide Corp., New York). High-Temperature Tungsten Base Alloys. U.S. Pat. 3,150,971, Sept. 29, 1964.

Uranium

By Charles T. Baroch[1]

◆

THE YEAR 1964 marked the second year of a gradual transition in the uranium industry from a military or weapons economy to one based on civilian uses. Nevertheless, about 600 mines produced 5.7 million tons of ore, yielding mill concentrate containing 11,847 tons of U_3O_8 valued at nearly $190 million. Receipts from foreign countries dropped to 5,297 tons, 40 percent less than in 1963, compared with a decline of 17 percent for domestic procurement.

TABLE 1.—Salient uranium statistics

(Short tons)

	1960	1961	1962	1963	1964
United States:					
Production:					
Mine (ore shipments)	7,970,211	8,041,329	7,052,870	[r] 5,645,921	5,666,252
Mill (U_3O_8 content) [1]	17,760	17,399	17,010	14,218	11,847
Imports: Concentrate (U_3O_8)	15,770	12,915	11,720	8,802	5,297
Free world: Production (U_3O_8 content)	41,130	36,490	34,600	30,200	25,600

[r] Revised.
[1] Concentrate marketed.

Two nuclear power reactors, one at Puente Higuero, P.R., and the other at Sioux Falls, S. Dak., were put into operation. Research and development on reactors continued, and technologic data accumulation reached new heights. Economic data showed that large nuclear power plants could be competitive with coal- and oil-fired plants in high-cost fuel areas. Sponsors stated that the Jersey Central plant, a 515-Mw reactor, would generate electricity at less than 4 mills per kilowatt-hour, competitive with fossil fuel at a cost of 20 cents per million British thermal units (Btu).

Reduction in uranium raw-materials procurement begun in 1963 was continued early in 1964 with the announcement by the President of a planned shutdown of four plutonium production reactors. This was based on a determination that production of weapons materials could be safely cut back.

LEGISLATION AND GOVERNMENT REGULATIONS

On August 26, 1964, President Johnson signed Public Law 88–489, amending the Atomic Energy Act of 1954 and providing for a transition from Government to private ownership of nuclear materials. Private ownership was permitted immediately, but AEC retained licensing powers and control over health, safety, and national security. After December 31, 1968, AEC may provide toll enrichment of nuclear material, and after December 31, 1970, AEC shall distribute special nuclear material only by sale rather than by new lease contracts. By June 30, 1973, any leased materials still under contract in private hands must be purchased by the private firms or returned to the Government. A new subsection of the law (161v) directs AEC to establish criteria setting forth terms and conditions under which toll enrichment shall be made available. In addition, toll enrichment shall not be offered on foreign material intended for use in domestic reactors to the extent necessary to assure the maintenance of a viable domestic uranium industry.

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[1] Commodity specialist, Division of Minerals.

Following studies by the Department of Defense and AEC about long-range requirements for plutonium and enriched uranium for national defense and peaceful uses, the President announced on January 8, 1964, a reduction in production of these materials. In April, he announced a further reduction for enriched uranium production. As a result, one of the five plutonium-production reactors at the Savannah River (S.C.) plant was closed in June, and three of the nine reactors at Hanford, Wash., were scheduled for closing, the first on December 30, 1964, and the others at 3-month intervals. Reduction in production of enriched uranium will take effect gradually and when completed in 1968 will represent an overall cut of 40 percent. Power requirements at the three gaseous diffusion plants were cut from a level of 5,250 megawatts (Mw) to about 3,900 Mw during 1964. They are scheduled to decrease by 1968 to 2,970 Mw. Expected employment cuts will total nearly 2,000 out of 8,300 workers at Hanford, about 500 out of 6,300 at Savannah River, and 380 out of 5,100 at the three gaseous diffusion plants.

During 1964, the States of Florida, North Carolina, and Kansas entered into agreements with AEC for transfer of certain phases of regulatory authority for control of byproduct, source, and special nuclear material in quantities not sufficient to form a critical mass. Six other States—Kentucky, California, Mississippi, New York, Texas, and Arkansas—previously made such agreements, and 22 other States have enacted enabling legislation authorizing an agreement. About 30 percent of current effective licenses for byproduct, source, and special nuclear material were under supervision of the nine agreement States. Eight other States were considering programs for assumption of regulatory authority.

AEC issued 15 amendments and proposed 7 new regulations and amendments, all were published in Title 10, Chapter I, of the Code of Federal Regulations (10 CFR 1).[2]

DOMESTIC PRODUCTION

Mine and Mill Production.—Approximately 600 mines in 14 States produced about 5.7 million tons of ore, about the same as 1963 and

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[2] U.S. Atomic Energy Commission. Major Activities in the Atomic Energy Programs. January–December 1964, pp. 374–378.

1.4 million tons less than 1962. New Mexico was again the leading State in value of production, followed by Wyoming, Utah, Colorado, Washington, Arizona, South Dakota, Texas, North Dakota, Alaska, California, Nevada, Oregon, and Montana.

TABLE 2.—Uranium mine and mill production in 1964, by States

State	Ore shipped				Concentrate purchased by AEC		
	Short tons	Value (thousands)	U_3O_8 content		Number of mills	Pounds U_3O_8	Cost (thousands)
			Percent	Pounds			
Arizona	102, 258	$3, 253	0. 37	759, 496	----------	----------	----------
Colorado	833, 282	13, 389	. 20	3, 500, 800	5	3, 601, 392	$28, 803
New Mexico	2, 093, 350	38, 203	. 22	9, 475, 676	4	9, 494, 487	75, 975
Oregon	27	2	. 86	465	----------	----------	----------
South Dakota	110, 147	1, 551	. 19	423, 195	----------	----------	----------
Utah	761, 180	26, 385	. 40	6, 029, 244	3	4, 126, 084	33, 007
Washington	147, 005	3, 601	. 29	863, 728	----------	----------	----------
Wyoming	1, 490, 353	27, 911	. 23	6, 950, 847	5	4, 431, 453	35, 461
Other States [1]	128, 650	2, 002	. 20	524, 322	4	2, 039, 863	16, 317
Total	5, 666, 252	116, 297	. 25	28, 527, 773	21	23, 693, 279	189, 563

[1] Ore shipments: Alaska, California, Montana, Nevada, North Dakota, and Texas. Concentrates: Arizona, South Dakota, Texas, and Washington.

Uranium ore was milled in 21 processing plants which produced concentrates containing 11,847 tons of U_3O_8, compared with 14,218 tons in 1963. The Union Carbide Corp. mill at Maybell, Colo., closed during the year, leaving 20 mills with AEC contracts at the end of the year. Under a program announced in November 1962, uranium producers were invited to submit proposals for deferral to 1967 and 1968 of a portion of the concentrates originally contracted for delivery by December 31, 1966. An additional quantity of concentrates, equal to that amount deferred to 1967 and 1968, would be purchased by AEC during 1969 and 1970. In addition, AEC may purchase up to 1,900 tons of U_3O_8 in concentrates during the period 1967–70 from small independent producers. The purpose of the extended purchase program was to provide a sustaining market for the uranium industry during the period when the commercial demand was expected to be low. Six companies (table 3) with expiration dates of December 31, 1970, were modified by the end of 1964, deferring a total of 8,804 tons of U_3O_8 for delivery in 1967 and 1968 and the delivery of an equal amount in 1969 and 1970. Negotiations were continuing on five other contracts at the end of the year, and AEC anticipated that the total deferment of deliveries would total about 15,000 tons.

Larger mines shut down in 1964, principally because of the cut back in procurement, included the famed Mi Vida near Moab, Utah, the Maybell in Colorado, the Lisbon and the Arrowhead in Wyoming, and the Kendrick Bay, the only producer in Alaska. Dawn Mining Co., 51-percent owned by Newmont Mining Corp. and the only producer in Washington, did not resume pit operations in the summer of 1964, but the mill operated on stockpiled ore and expected to continue to do so to mid-1965, when the existing production contract would be completed. One of the few new developments was a lignite-burning plant near Bowman, N. Dak., designed by Kermac Nuclear Fuels Corp. to reduce 225 tons of raw lignite per day into about 75 tons of uranium-bearing ash, which is shipped to the Kermac mill at Grants, N. Mex., for further processing. A similar plant was started by Union Carbide Corp. at Belfield, N. Dak., to provide feed for its mill at Rifle, Colo.

Refining and Enrichment.—Implementing reduction in production of enriched uranium and plutonium announced by the President in early 1964, the uranium hexafluoride plant at Paducah, Ky., operated for AEC by Union Carbide Corp., was placed on a standby status. The privately owned Allied Chemical Corp. plant at Metropolis, Ill., although ready to produce UF_6 directly from concentrates or UF_4 from refinery uranium oxide, was also placed on standby. Both plants produced UF_6 for the gaseous diffusion cascades before June 30, 1964. Refinery operations at Weldon Spring, Mo., operated by Mallinckrodt Chemical Works, were also reduced, and a new prototype electrolytic cell for reduction of uranium was placed in operation there.

Plans were announced by AEC for gradually reducing the production of enriched uranium at the gaseous diffusion plants at Oak Ridge, Tenn., and Paducah, Ky., both operated by Union Carbide Corp., and at Portsmouth, Ohio, operated by Goodyear Atomic Corp. Based on consumption of electricity, power usage was to be reduced from 4,850 Mw on July 1, 1964, to 3,915 Mw by July 1, 1965. Further reduction to 2,970 Mw was planned by 1968. Operations in the other process buildings at all three plants continued at reduced levels. No privately owned uranium enriching capabilities were established or planned, but AEC enrichment of privately owned material can be undertaken under contract beginning January 1, 1969, according to the 1964 Private Ownership Act.

TABLE 3.—Uranium processing plants, December 31, 1964

State and company	Plant location	Contract expiration date	Tons U_3O_8 deliverable under contract from Jan. 1, 1964
Arizona: El Paso Natural Gas Co.	Tuba City	Dec. 31, 1966	820
Colorado:			
American Metal Climax, Inc.	Grand Junction	do	1,494
Cotter Corp.	Canon City	Feb. 28, 1965	239
Union Carbide Corp.	Rifle	Dec. 31, 1966[1]	4,660
Do	Uravan		
New Mexico:			
The Anaconda Company	Grants	Dec. 31, 1970	5,221
Homestake-Sapin Partners	do	Dec. 31, 1966[1]	[2]10,132
Kermac Nuclear Fuels Corp.	do	Dec. 31, 1970	11,044
Vanadium Corporation of America	Shiprock	Dec. 31, 1966[1]	1,272
South Dakota: Mines Development, Inc.	Edgemont	do	1,038
Texas: Susquehanna-Western, Inc.	Falls City	do	351
Utah:			
Atlas Corp.	Moab	Dec. 31, 1970	7,719
Do	Mexican Hat		
Vitro Chemical Co.	Salt Lake City	Dec. 31, 1966	685
Washington: Dawn Mining Co.	Ford	do	864
Wyoming:			
Federal-Radorock-Gas Hills Partners	Fremont County	do.[1]	[3]2,186
Petrotomics Co.	Carbon County	do	1,002
Union Carbide Corp.	Natrona County	Dec. 31, 1970	1,550
Utah Construction & Mining Co.	Fremont County	do	4,257
Western Nuclear, Inc.	Jeffrey City	do	4,349

[1] These companies were negotiating stretchout agreements at yearend.

[2] Includes 4,642 tons under contract to United Nuclear Corp. which is treated in Homestake-Sapin Partners mill under a tolling agreement.

[3] Federal-Radorock-Gas Hills Partners also produced concentrates for the account of Susquehanna-Western, Inc., under a tolling agreement.

TABLE 4.—Enriched uranium furnished to industry, excluding the weapons production chain

(Pounds)

	Fiscal year				
	1960	1961	1962	1963	1964
Furnished as UF_6	190,040	261,025	276,900	221,070	256,620
Furnished in forms other than UF_6	7,500	15,210	6,610	8,630	4,490
Total	197,540	276,235	283,510	229,700	261,110

Source: AEC Annual Report for 1964, p. 272.

CONSUMPTION AND USES

Uranium continued to be used principally for weapons production and as nuclear fuel for power, propulsion, and irradiation reactors.

Weapon and Explosive Applications.—AEC under Presidential authorization and with guidance from the Department of Defense (DOD) continued production of plutonium and research and development of new uses. Plutonium was produced in eight graphite-moderated reactors at Hanford, Wash., and five heavy water reactors at Savannah River, S.C. One reactor at Hanford was shut down on December 31, 1963, at the time the New Production Reactor (NPR) achieved initial criticality. NPR functioned well during test programs and will be used for production of electricity in 1965, as well as for production of nuclear materials. One reactor at the Savannah River plant was closed on June 15, 1964, and, under plans for the general cutback in special nuclear materials, three reactors were scheduled for closing at Hanford during the first 6 months of 1965.

Sandia Laboratory at Albuquerque, N. Mex., and Livermore, Calif., Los Alamos Scientific Laboratory at Los Alamos, N. Mex., and the University of California Lawrence Radiation Laboratory at Livermore, Calif., continued research and development of weapons designed to meet DOD requirements. Included in the laboratory effort was the design and fabrication of devices and the development of test-detection methods in the continuing underground test program at the Nevada Test Site. Under the nuclear Test Ban Treaty of August 5, 1963, nuclear detonations in the atmosphere, outer space, and underwater were prohibited, but limited underground tests were permitted. Tests announced in 1964 included 21 U.S. weapons-related tests, 1 U.S.-U.K. test of a U.K. device, 6 Plowshare and 1 Vela experiments. Plowshare was the code name for peaceful industrial and scientific applications for nuclear explosives, and the Vela program was for the detection of nuclear explosions to detect violations of the test-ban treaty and to maintain knowledge of the nuclear activity of other nations.

Low-radiation blasting techniques developed under the Plowshare program were designed to clear the way for possible excavation projects. Among those seriously considered were the possibilities of a new sea-level canal to replace the Panama Canal, a mountain-pass excavation through the Bristol Mountains near Amboy, Calif., and a divide cut to connect the Tennessee and the Tombigbee rivers in the northeast corner of Mississippi. Other applications of nuclear explosives considered were for mining massive, deeply buried mineral deposits; breaking up large deposits of low-grade copper ore to permit its leaching in place; breaking and heating petroleum and oil shale deposits to liberate the oil; and the cracking and fracturing of tight natural-gas reservoirs to increase the permeability and improve production. Scientific applications of nuclear explosions, also yielded information in neutron physics, heavy-element chemistry, and geophysical investigations.

Civilian Reactors.—Net electrical-generating capacity of 13 central-station-type nuclear power plants and Experimental Breeder Reactor No. 2 totaled 1,091 Mw; 6 plants designed to aggregate 1,464 Mw were under construction; 2 others for 963 Mw were planned. All 21 plants were to be completed by 1969 and would total 3,518 Mw of electrical capacity. The Boiling Nuclear Superheat Reactor (BONUS) and the Pathfinder Atomic Power Plant achieved criticality (a self-sustaining chain reaction) during 1964, and the Elk River Reactor was operated at full power in February for the first time. AEC issued permits for the plants at San Clemente, Calif.; Haddam Neck, Conn.; and Oyster Creek, N.J., and construction was started. Pacific Gas & Electric Co. (PG&E) withdrew its application to build a 313,000-kilowatt nuclear plant at Bodega Bay, north of San Francisco. Two reports regarding the safety hazard presented by the Bodega site presented different conclusions. AEC's Advisory Committee on Reactor Safeguards concluded that the proposed reactor could be operated at Bodega Bay without undue hazard. The AEC regulatory staff stated there was uncertainty in the safeguards against the effects of a major earthquake, as the reactor site was near the San Andreas fault. Rather than face any risks at all, PG&E withdrew from the site in spite of already having spent $4 million in preparation and inspection.

Economic data were released early in 1964 by Jersey Central Power & Light Co., indicating that a generating cost of less than 4 mills per kilowatt-hour was expected of the Oyster Creek plant. According to this estimate, nuclear power would be competitive with power from a fossil-fueled plant where fuel cost at power-plant site was about 20 cents per million British thermal units (Btu). Coal delivered at New Jersey sites cost 34 cents per million Btu. The cost of the plant was estimated at $68 million.

Cooperative arrangements for two prototype converter-reactor plants were announced by AEC. Converter reactors incorporate fertile nuclear material in or around the fuel core so that surplus neutrons from fissioning fuel will produce or "breed" new fissionable fuel. One proposal was submitted by the Rochester (N.Y.) Gas and Electric Corp. for a 260-Mw high-temperature gas-cooled reactor, and the other was by the Department of Water Resources of California for a 525-Mw seed-blanket reactor employing the thorium fuel cycle. The California plant, if located on the coast, may include a sea water desalting facility.

Use of nuclear reactors for providing both electricity and desalted water from very large plants received a strong impetus in March 1964 from a study by an Interagency Task Group under the Office of Science and Technology. The study concluded that technology for such large combined plants could be developed by about 1980 at costs which could

TABLE 5.—Principal civilian nuclear power reactors [1]

Reactor	Location	Electrical capacity, kilowatts	Initial criticality
Operable:			
Shippingport Atomic Power Station	Shippingport, Pa	60,000	1957
Dresden Nuclear Power Station	Morris, Ill	200,000	1959
Yankee Nuclear Power Station	Rowe, Mass	175,000	1960
Big Rock Nuclear Power Plant	Big Rock Point, Mich	72,000	1962
Elk River Reactor	Elk River, Minn	23,000	1962
Indian Point Unit No. 1	Indian Point, N.Y	255,000	1962
Hallam Nuclear Power Facility	Hallam, Nebr	75,000	1962
Humboldt Bay Power Plant	Humboldt Bay, Calif	50,500	1963
Piqua Nuclear Power Facility	Piqua, Ohio	11,400	1963
Carolinas-Virginia Tube Reactor	Parr, S.C	17,000	1963
Enrico Fermi Atomic Power Plant	Lagoona Beach, Mich	60,900	1963
Experimental Breeder Reactor No. 2	Idaho Falls, Idaho	16,500	1963
Boiling Nuclear Superheat Reactor	Puente Higuera, P.R	16,300	1964
Pathfinder Atomic Power Plant	Sioux Falls, S. Dak	58,500	1964
Total operable capacity		1,091,100	
Under construction:			
Peach Bottom Atomic Power Station	Peach Bottom, Pa	40,000	1965
La Crosse Boiling Water Reactor	Genoa, Wis	50,000	1965
Experimental Gas-Cooled Reactor	Oak Ridge, Tenn	21,900	1965
San Onofre Nuclear Generating Station	San Clemente, Calif	375,000	1966
Connecticut Yankee Atomic Power Station	Haddam Neck, Conn	462,000	1967
Jersey Central Power & Light Co	Oyster Creek, N.J	515,000	1969
Planned:			
Malibu Nuclear Plant	Corral Canyon, Calif	463,000	1967
Nine Mile Point Plant	Oswego, N.Y	500,000	1968

[1] Including experimental reactors of over 10,000-kilowatt generating capacity.

Source: Adapted from AEC Annual Reports.

be reasonably amortized. Later in the year, a program was prepared to speed the development of desalination technology in which AEC would develop nuclear reactors for the dual-purpose plant and the Department of the Interior Office of Saline Water would develop desalting techniques.[3] A feasibility study, sponsored jointly by the Metropolitan Water District of Southern California and the two Government agencies, was initiated by contracts with six companies for conceptual design studies for a plant to produce 50 million gallons per day of desalted sea water.

Few changes were made in 1964 in the structure of the principal producers and fabricators of uranium materials and fuels. Kerr-McGee Oil Industries announced a new facility to process ceramic uranium oxide and pellets and to operate a uranium recovery circuit for use by reactor builders. Nuclear Fuel Services, Inc. (NFS), a subsidiary of W. R. Grace & Co. continued construction on a facility at West Valley, N.Y., for reprocessing irradiated reactor fuels, the first domestic privately owned plant of its kind. NFS also completed construction of a new enriched uranium oxide plant at Erwin, Tenn., which replaced three small production facilities. American Radiator & Standard Sanitary Corp. withdrew from the nuclear-fuel fabrication business and assigned all incompleted fuel contracts to Sylvania Electric Products, Inc. The Dow Chemical Co. and Westinghouse Electric Corp. have joined in a research and development program to study new methods for reprocessing nuclear fuels.

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[3] Chemical and Engineering News. Interior and AEC Spell Out Desalting Plans. V. 42, No. 45, Nov. 9, 1964, pp. 42, 45.
Chemical Engineering. Water Desalting and Atomic Power Are Teaming Up. V. 71, No. 24, Nov. 23, 1964, pp. 82, 84, 86, 88.

TABLE 6.—Principal producers of uranium materials and fabricators of uranium fuels

Company and principal location	Metal, oxides, and compounds	Coated particles	Fabricators of uranium fuels
Aerojet General Nucleonics, San Ramon, Calif.			X
Allis-Chalmers Manufacturing Co., Greendale, Wis.			X
Atomics International, Canoga Park, Calif.			X
The Babcock & Wilcox Co., Lynchburg, Va.			X
Battelle Memorial Institute, Columbus, Ohio			X
The Carborundum Co., Niagara Falls, N.Y.			X
Combustion Engineering, Windsor, Conn.			X
Coors Porcelain Co., Golden, Colo.			X
Davison Chemical Division, W. R. Grace & Co., Erwin, Tenn.	X	X	X
Diamond Alkali Co., Painesville, Ohio		X	
General Dynamics Corp., San Diego, Calif.		X	X
General Electric Co., San Jose, Calif.	X		X
Kerr-McGee Oil Industries, Inc., Cushing, Okla.	X		
Martin Marietta Corp., Baltimore, Md.			X
Metals & Controls Inc., Attleboro, Mass.			X
Minnesota Mining & Manufacturing Co., St. Paul, Minn.		X	
National Carbon Co., Lawrenceburg, Tenn.		X	
National Lead Co., Albany, N.Y.	X		X
Nuclear Fuel Services, Inc., Erwin, Tenn.	X	X	X
Nuclear Materials & Equipment Corp., Apollo, Pa.	X	X	X
Nuclear Metals Inc., Concord, Mass.			X
Sylvania Electric Products, Inc., Hicksville, N.Y.			X
United Nuclear Corp., Hematite, Mo., and New Haven, Conn.	X	X	X
Westinghouse Electric Corp., Pittsburgh, Pa.			X

Source: AEC Annual Reports.

The nuclear ship, *Savannah*, a joint project of the Maritime Administration, U.S. Department of Commerce, and AEC, made four trips to Europe carrying passengers on each voyage. It traveled more than 75,000 miles under nuclear power, visiting 14 foreign and 24 domestic ports, during which less than 3 percent of its initial fuel loading was used. Other studies and developmental work were continued on nuclear power for maritime applications, largely under proposals made by The Babcock & Wilcox Co., General Electric Co., and United Nuclear Corp. American Export-Isbrantsen Lines, contract operator of the *Savannah*, declared its interest in four nuclear-powered merchant ships to be used in New York-Far East trade routes.

Military Reactors.—By the end of 1964, Congress had authorized 92 nuclear-powered submarines, of which 51, including 29 of the Polaris missile-launching type, were in operation. Operational nuclear-powered surface naval ships included the aircraft carrier *Enterprise*, the guided-missile cruiser *Long Beach*, and two guided-missile destroyer leaders, the *Bainbridge* and the *Truxton*.

Prototypes of stationary and portable land-based military plants were operated at Fort Belvoir, Va.; Fort Greeley, Alaska; McMurdo Station, Antarctica; Air Defense Command, Sundance, Wyo.; and National Reactor Testing Station, Idaho. The Portable Medium Power Plant at Camp Century, Greenland, was dismantled and placed in standby in the United States after 3 years of operation. The Fort Belvoir plant was modernized with a new transistorized system of control.

Research and Test Research.—A total of 91 test, research, and teaching reactors were operable in 1964, consisting of 4 for general irradiation tests, 11 for special tests, 35 for research, and 41 for teaching; 14 others were being built. An operating license was issued to The Babcock & Wilcox Co. for its test reactor located near Lynchburg, Va.

Foreign Reactors.—Up to the end of 1964, central electric-power reactors built for export and subject to U.S. safeguards included four operable at Kahl-am-Main, West Germany (15,600 kilowatts); Garigliano, Italy (150,000 kilowatts); Tokai-Mura, Japan (11,700 kilowatts); and Trino (SELNI), Italy (240,000 kilowatts). Three are being built at Chooz, France (210,000 kilowatts); Tarapur, India (380,000 kilowatts); and Gundremmigen, West Germany (237,000 kilowatts). One is planned for Zorita, Spain (140,000 kilowatts). A total of 41 U.S.-built research reactors were operable, 11 were being built, and 1 was planned.

Radioisotopes.—In the first 11 months of 1965, 10,387 shipments totaling 573,917 curies of processed radioisotopes, having a gross value of $2.12 million, were made from the Oak Ridge (Tenn.) National Laboratory. AEC proposed formal procedures for its withdrawal from routine production and distribution of radioisotopes which are reasonably available from commercial producers. During the past 5 years AEC has withdrawn from commercial production of 10 radioisotopes; those dropped in 1964 were Cr^{51}, Fe^{55}, Co^{58}, Cs^{134}, Ce^{141}, and Sr^{85}.

Fission products separated and purified at the Hanford Works of AEC, Richland, Wash., consisted of 1,400 kilocuries of Sr^{90}, 396 kilocuries of Cs^{137}, and 500 kilocuries of Ce^{144}. Used principally as isotopic fuels, these were sent to Oak Ridge National Laboratory and the Nuclear Division of the Martin Co., Quehanna, Pa., a subsidiary of Martin Marietta Corp. The two processors, together with Nuclear Materials & Equipment Corp., Apollo, Pa., are cooperating on development of acceptable fission-product isotopic fuels for terrestrial and space application.

Other AEC installations that continued to produce isotopes were Argonne (Ill.) National Laboratory; Brookhaven National Laboratory, Upton, N.Y.; and Mound Laboratory, Miamisburg, Ohio. Industrial producers of radioisotopes include Abbott Laboratories, Oak Ridge, Tenn.; General Electric Co., San Jose, Calif.; Iso/Serve, Inc., Cambridge, Mass.; Nuclear Materials & Equipment Corp., Apollo, Pa.; Nuclear Science & Engineering Corp., Pittsburgh, Pa.; Union Carbide Corp., Tuxedo, N.Y.; Volk Radiochemical Co., Skokie, Ill; and Western New York Research Center, Buffalo, N.Y.

Use of radioisotopes continued to expand dramatically. More than 200 different applications of tracers in industry were described, and radioisotopes were used for many types of level, thickness, density, and moisture gages. Gamma radiography was standard practice in many metals and engineering industries, and bulk and cell irradiation for biological sterilization and chemical catalysis increased in scope.[4] For instance, AEC issued a license to Ethicon, Inc., for a 750,000-curie cobalt 60 irradiator at Sommerville, N.J., to be used principally for sterilizing packaged surgical sutures.

Isotopic power for specialized applications and isolated locations progressed during 1964 through the AEC Systems for Nuclear Auxiliary Power (SNAP) program. A nuclear generator fueled with about 20 pounds of strontium 90 titanate and generating about 60 watts went into unattended operation in a weather station in the Gulf of Mexico, the first of its kind. A similar generator was put in to operate an unmanned beacon in Baltimore Lighthouse, south of Baltimore in Chesapeake Bay. A nuclear-powered navigational aid was implanted by the Navy in 15,000 feet of water in the Atlantic ocean about 750 miles east of Jacksonville, Fla. Heat produced by fuel pellets containing about 3 pounds of strontium 90 produces 7 watts of continuous power by means of 60 sets of thermocouples. The power produces sound through a transducer and is used for underwater navigational experiments. Other SNAP generators were being developed for space use in satellites.

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[4] Radiation Effects Information Center, Columbus, Ohio. The Beneficial Uses of Radiation Effects. U.S. Dept. of Commerce, OTS, AD 601,493, 1964, 20 pp.
Cooper, Daniel J. Radiation Processing. Internat. Sci. and Technol., No. 27, March 1964, pp. 22–34.

Another new development was radiation-processing of plastic-impregnated wood by which the hardness of pine can be increased about 700 percent.[5] Many new uses for radioisotopes were initiated for processing, sterilizing, and preserving foods. Irradiation, usually with a high-gamma source like cobalt 60, will destroy bacteria and insects without contaminating it with pesticides. Construction was started on a pilot-scale bulk grain irradiator at Savannah, Ga., which will process 5,000 pounds of grain per hour to kill infesting insects.[6] The Marine Products Development Irradiator started operation at Gloucester, Mass., and tests show that certain seafoods can be stored for as long as 24 days when they have been subjected to low doses of gamma radiation. Portable fish irradiators were being developed for use on fishing vessels. By pasteurizing both fish and the sea water in which they are kept, the fish may be kept fresh while in the hold of the ship.

PRICES AND SPECIFICATIONS

Uranium Ore and Concentrate.—Since March 31, 1962, AEC has obtained uranium concentrate under contracts with mills, and the mills have purchased part of their ore supply on the open market. The last schedule of ore prices given by AEC was known as Circular 5 which expired in 1962, but most mills have continued to use similar rates as the basis of ore purchases. Circular 5 stipulated a base price ranging from $1.50 per pound of U_3O_8 on ore grade of 0.10 percent to $3.50 per pound on ore containing 0.20 percent U_3O_8 or better. The average value of uranium ore, based on data supplied to the Bureau of Mines, was $20.52 per short ton, equivalent to $4.08 per pound of U_3O_8. The AEC contract price for specification-grade concentrates continued to be $8 per pound of contained U_3O_8. This price will continue in the new contracts through calendar year 1968. For quantities delivered in 1969 and 1970, the price per pound of U_3O_8 in acceptable concentrate will be 85 percent of the allowable production cost per pound plus $1.60, subject to a maximum price of $6.70.

Uranium Metal.—Normal uranium metal was quoted for most of 1964 to the end of the year at $18 per pound, down from $24 in 1963. Prices for depleted uranium, in the form of uranium hexafluoride, were unchanged and ranged from \$2.50 per kilogram of contained metal for material containing less than 0.38 percent U^{235} to \$22.60 per kilogram for uranium containing 0.7 percent U^{235}.

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[5] Industrial and Engineering Chemistry. Wood Modified with Monomers and γ-Rays. V. 56, No. 3, March 1964, pp. 11–12.

[6] U.S. Department of Agriculture. Cobalt 60 Bulk Grain Irradiator. U.S. Dept. of Commerce, OTS, BNL 810 (T-312), June 30, 1963, 50 pp.

Special Nuclear Materials.—Base charges for enriched uranium as uranium hexafluoride remained unchanged since July 1, 1962, and varied with the degree of enrichment from \$4.77 to \$9.59 and \$12.01 per gram of U^{235} content for 0.010, 0.050, and 0.90 weight-fraction material, respectively. Very highly enriched uranium became available in limited quantities in April 1964, containing to 97.65 percent U^{235}; the base charge for this material was established at \$12,250.40 per kilogram or \$12.55 per gram of contained U^{235}.

Base charges by AEC for Pu^{239}, Pu^{241}, and U^{233} were unchanged from 1963. Plutonium was \$43 per gram of contained Pu^{239} and Pu^{241}; for uranium enriched in U^{233}, the charge was \$82 per gram of contained U^{233}. Prices were subject to adjustment for the presence of other uranium isotopes.

FOREIGN TRADE

Imports of uranium concentrate as reported by AEC totaled 5,297 tons of contained U_3O_8 or 31 percent of total domestic procurement, compared with 38 percent in 1963; 3,534 tons came from Republic of South Africa, and 1,763 tons came from Canada. Shipments from South Africa and Canada were the result of contracts entered into during the early stages of the procurement program. Incompleted balances on these contracts were 3,263 and 1,435 tons, respectively, for South Africa and Canada, and these were scheduled for completion in 1966.

Exports of ores, concentrates and compounds to Mexico, Argentina, Brazil, France, West Germany, Italy, the Netherlands, Japan, and Australia aggregated 1,466 pounds valued at \$20,373.

Uranium metal and uranium-bearing alloys, including semifabricated and fabricated forms, except special nuclear material were exported to Canada, Venezuela, France, West Germany, Italy, Spain, Sweden, Switzerland, United Kingdom, Israel, Japan, and Republic of South Africa, aggregating 6,896 pounds valued at \$144,890.

Approximately 20 imports and 280 exports of special nuclear material were made in 1964. The principal imports consisted of 12 shipments of irradiated fuel elements from research reactors in Sweden and Canada. Exports of special nuclear materials had a value of \$7.4 million and went to 20 countries. Five countries—France, Belgium, Canada, West Germany, and Italy, listed in order of decreasing value—received over 80 percent of the shipments.

Since 1954, through 1964, AEC has distributed abroad special nuclear and other materials having an approximate total value of \$117.5 million, of which \$66.9 million was by sale, \$31.7 million on lease, and \$18.9 million on deferred-payment sales. The first shipment to Italy of 16 fuel elements for a portion of the first core of the SELNI (Societa Elettronucleare Italiana) plant, a 242-Mw boiling water reactor, was made in March. As part of a deferred-payment sales contract covering a fuel supply for 20 years, the full core will consist of almost 90,000 pounds of uranium enriched in 3 grades of 2.73, 3.12, and 3.9 percent U^{235}. The complete core was valued at about $11.5 million.

The ports of New York, Tampa, Portland (Oreg.), and Redwood City (Calif.) permitted the shipment of irradiated fuels for the first time, raising to 21 the domestic ports allowing such shipments.

WORLD REVIEW

NORTH AMERICA

Canada.—Of six mines and mills operating at the beginning of 1964, only three remained in operation at the end of the year. These were Eldorado Mining & Refining, Ltd., at Beaverlodge in Saskatchewan, and Denison Mines, Ltd., and the Nordic mill of Rio Algom Mines, Ltd., at Elliot Lake, Ontario. Gunnar Mining, Ltd., which ceased mining in 1963 and milling in early 1964 was unable to supply about 1.2 million pounds of U_3O_8 on its contract with the United Kingdom. Other Canadian producers were invited to tender bids for an added contract for this amount of U_3O_8 at a price slightly more than $4.18 per pound. The deciding factor was the number of man-days of employment the producer would guarantee to provide in completing the contract. Denison Mines was the successful bidder, and the added contract assured operation of the mine to mid-1965, at least.[7]

TABLE 7.—Free world production of uranium oxide (U_3O_8) by countries[1, 2, 3]

(Short tons)

Country [1]	1960	1961	1962	1963	1964
North America:					
Canada	12,748	9,641	8,430	8,141	6,914
United States	[4] 17,760	[4] 17,399	17,010	14,218	11,847
South America:					
Argentina	[e] 7	[e] 5	4	11	[e] 12
Europe:					
Finland [e]	40	20	------	------	------
France [5]	1,379	2,078	2,601	2,021	1,910
Spain [e]	60	55	55	55	50
Sweden [e]	10	10	10	10	9
Africa:					
Congo (Léopoldville), Republic of the	1,200	------	------	------	------
South Africa, Republic of	6,409	5,468	5,024	4,532	4,445
Oceania:					
Australia [e]	1,300	1,600	1,400	1,200	370
Free world total [1 2]	41,130	36,490	34,600	30,200	25,600

[e] Estimate.

[1] Uranium is also known to have been produced in Colombia, India, Italy, Japan, Portugal, and West Germany, but production data are not available; however, an estimate for these countires has been included in the world total.

[2] Uranium is also believed to be produced in Czechoslovakia, East Germany, Hungary, U.S.S.R., and other Soviet-bloc countries, but production data are not available, and no estimate for these countries has been included in the world total. Estimates of production for the Soviet-bloc countries range from 10,000 to 20,000 tons per year.

[3] This table incorporates some revisions. Data do not add exactly to totals shown because of rounding where estimated figures are included in the detail.

[4] Data represent deliveries to AEC. Includes uranium production from phosphate rock in eastern United States.

[5] Malagasy Republic and Gabon included with France.

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[7] Northern Miner (Toronto, Canada). Termination of "U" Stockpiling to Force Some Mines to Close. V. 50, No. 7, May 20, 1964, pp. 1, 8.

———. Denison Contract. V. 50, No. 12, sec. 1, June 11, 1964, p. 2.

An abundantly illustrated description of the Canadian uranium industry was published primarily for distribution at the Third United Nations Conference in Geneva. The history of all Canadian uranium mines, beginning with the discovery of the rich pitchblende ore at Port Radium, Great Bear Lake, was reviewed in a publication of Eldorado Mining and Refining, Ltd.[8]

EUROPE

Finland.—An agreement between the Finnish Ambassador to Vienna and the Director of the International Atomic Energy Agency (IAEA) would permit Finland to obtain 10-percent-enriched uranium from U.S.S.R. This is reported to be the first time that Russia has agreed to suply enriched uranium to another country through IAEA.[9]

France.—Electricité de France (EDF) placed its second nuclear power plant (200-Mw) in operation in 1964. EDF1, 70-Mw capacity, began power operation in June 1963; EDF3, 480-Mw capacity, was under construction for planned operation in 1966. All are located at Chinon. Construction of EDF4, designed for 500 Mw, was started at St. Laurent des Eaux on the Loire. All four reactors are French developed, using natural uranium fuel, graphite moderator, and carbon dioxide coolant. Despite the recent discovery of large quantities of natural gas and oil in the Sahara, France continued to pursue a vigorous program of nuclear-power station construction.[10]

Construction continued on the 266-Mw reactor at Chooz near the Belgian border. This power station, being built by Société d'Energie Nucléaire Franco-Belge des Ardennes, will be the first in France to use a pressurized water reactor which with many of the subsidiary buildings will be underground in rock caverns along the Meuse River. Fuel will be enriched with 3.5 percent U^{235}, probably from the United States. Most other components will be made in Europe.[11]

Germany, West.—In spring 1964, decisions were made to proceed with a new program to include a 25-Mw boiling-water-superheater reactor at Kahl, a 240-Mw (including an 85-Mw superheater) boiling-water reactor station at Darme near Lingen, a 282-Mw pressurized water reactor at Obrigheim, and a 100-Mw gas-cooled, heavy-water reactor for Lower Bavaria. This schedule provides for nine reactors to be in operation by 1969. Only one, a 15-Mw boiling-water reactor at Kahl, is now in operation, but four others aggregating 322 Mw are under construction and due for completion in 1965 and 1966.[12]

Italy.—The Enrico Fermi nuclear power plant of Societa Elettronucleare Italiana (SELNI) went critical in Trino on June 21, 1964. It was designed by Westinghouse Electric Corp. for a power output of 240 Mw and was the largest nuclear power plant in Europe and the largest closed-cycle water reactor in operation in the world.[13]

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[8] Eldorado Mining and Refining Ltd. (Ottawa, Canada). Uranium in Canada. 1964, 134 pp.

[9] Bureau of Mines. Mineral Trade Notes. V. 59, No. 1, July 1964, p. 45.

[10] Nuclear Engineering. Progress in France, CEA Annual Report, 1963/64. V. 9, No. 102, November 1964, pp. 404–406.

[11] Atomics. V. 17, No. 3, May/June 1964, pp. 34–35.

[12] Nucleonics. W. Germany's Great Leap: 15 Mwe Now; 1,000 Mwe by Late '60s. V. 22, No. 12, December 1964, pp. 24–25.

[13] Atomics. V. 17, No. 4, July/August 1964, p. 4.

Spain.—Unión Eléctrica Madrileña selected a Westinghouse Electric Corp. proposal to build the first nuclear power station in Spain. The 140-Mw plant will be built at Zorita de los Canes, about 40 miles east of Madrid. Spain will supply uranium concentrates to the United States in return for the necessary quantity of 3.2-percent enriched uranium.[14] A second reactor of 500-Mw capacity was agreed upon to be cooperatively financed by Spanish and French interests. The new station will be a replica of the French EDF4 power station under construction at St. Laurent des Eaux. Electricité de France will contribute 25 percent of the cost of the plant and take about 25 percent of the power in repayment.[15]

United Kingdom.—A second nuclear-power program, announced in an official white paper, plans to double the British nuclear-power effort during the next decade and calls for construction between 1970 and 1975 of four new stations with a total of eight reactors costing about $1.1 billion. The first plan, initiated in 1955, is expected to be completed in 1969, when nine stations will have an electrical capacity of nearly 5,000 Mw. The United Kingdom Atomic Energy Authority (UKAEA) favors the Magnox system developed in England, which uses natural uranium as fuel in gas-cooled reactors. The British Central Electric Generating Board stated that recent successes of the American water-cooled reactor stations has warranted further consideration before firm commitments are made for the new reactors. Consequently, the new program will be flexible and will also consider tenders from British industry for water-moderated reactor systems of proved design.[16]

Britain claims that the Springfields Works of the UKAEA, near Preston, is the largest center in the world for manufacturing uranium fuel for nuclear power.[17] A contract was made between UKAEA and Italian authorities for reprocessing fuel elements from the Latina Nuclear Power Station and for recovery and return of plutonium produced in operating the reactor. This work will be done at the Windscale Works.[18]

ASIA

India.—Indian Rare Earths, Ltd., started building a uranium mill at Jaduguda, Bihar State, having a capacity of 1,000 tons of ore per day.[19] A plutonium extraction plant was completed at Trombay, which is capable of processing 30 tons of uranium a year and is designed to yield about 1 kilogram of plutonium from 1 metric ton of uranium. Only five other countries have plutonium extraction plants—United States, Great Britain, France, Norway, and U.S.S.R.[20]

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[14] Nucleonics. Spain's 1st N-Plant: Westinghouse Selected. V. 22, No. 4, April 1964, p. 27.

Nuclear Engineering (London). Zorita Enriched Uranium Deal. V. 22, No. 98, July 1964, p. 235.

[15] Nuclear Engineering (London). French Reactor for Spain. V. 9, No. 102, November 1964, p. 393.

[16] Nuclear Engineering (London). The Second Nuclear Power Programme. V. 9, No. 96, May 1964, pp. 158–159.

[17] Chemistry and Industry (London). United Kingdom Atomic Energy Authority Springfields Works. No. 26, June 27, 1964, pp. 1183–1184.

[18] Chemical Trade Journal and Chemical Engineer (London). Britain to Re-Process Italian Nuclear Fuel. V. 155, No. 4039, Nov. 6, 1964, p. 624.

[19] World Mining. 1,000 Ton Per Day Uranium Mill to be Built at Jadugoda. V. 17, No. 8, July 1964, p. 61.

[20] Mining and Minerals Engineering (London). Screenings—Asia. V. 1, No. 3, November 1964, p. 84.

India and Sweden, under a 1961 agreement on the peaceful uses of atomic energy, agreed to conduct a cooperative study of the feasibility and economics of building a power station with a pressurized heavy-water reactor in India. It would have a power output of about 200 Mw, using natural uranium and producing plutonium. Other types of fueling, such as uranium enriched with plutonium and thorium enriched with plutonium or uranium 233, will be investigated.[21]

AFRICA

Gabon.—The uranium deposit at Mounana was estimated to contain about 1 million tons of ore with an average uranium content of 0.4 percent. Open-pit mining has been used and will mine to a depth of 250 feet. This will produce about one-half million tons of ore, and the balance of the ore will be recovered through a 650-foot shaft. The ore is in Precambrian sandstone. It was treated by leaching with sulfuric acid, and the uranium was precipitated with milk of magnesia as uranate of magnesium. Dried concentrate was shipped to France.[22]

Malagasy Republic.—Uranothorianite, first exploited in 1954, became the country's second most valuable mineral export. The host rock, pyroxenite, contains about 0.3 to 0.4 percent uranothorianite as an accessory mineral. The uranothorianite concentrate produced on jigs and tables, contains from 18 to 23 percent U_3O_8 and about 60 percent ThO_2 and is shipped to France. The French Atomic Energy Commission purchases the concentrates under contract and pays $6 per pound of U_3O_8 and $0.74 per pound of ThO_2 for high-thorium product and $10.60 per pound of U_3O_8 and $0.21 per pound of ThO_2, less $0.42 per pound, for other concentrates.[23]

South Africa, Republic of.—General Mining & Finance Corp., Ltd., erected facilities for producing nuclear-grade, 99.99-percent U_3O_8. Other South African operators make a product containing about 90-percent U_3O_8 which has to be refined further by the importer. The improvement was attained by incorporating a solvent-extraction step in the conventional flow circuit. The new plant was erected at the Buffelsfontein Gold Mining Co., Ltd., property in the Klerksdorp area, where a pilot plant has been in operation since 1961.[24]

OCEANIA

Australia.—An illustrated booklet consisting of a collection of articles on the history and development of the uranium mining industry in Australia was published.[25] The Australian AEC attempted to maintain interest in the uranium industry, despite all contract arrangements for supplying uranium having been completed. Production of uranium oxide at Rum Jungle continued, the concentrates being stockpiled, and further aerial and ground surveys were financed by the

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[21] Bureau of Mines. Mineral Trade Notes. V. 59, No. 1, July 1964, p. 46.

[22] Mining and Minerals Engineering (London). The Mounana Uranium Deposit. V. 1, No. 3, November 1964, pp. 87–88.

[23] Bureau of Mines. Mineral Trade Notes. V. 58, No. 4, April 1964, pp. 46–48.

[24] Mining Magazine (London). Buffelsfontein's Nuclear Grade Uranium Project. V. 111, No. 6, December 1964, pp. 389, 391.

[25] Australian Atomic Energy Commission (Coogee, N.S.W., Australia). Uranium in Australia. 1964, 64 pp.

Commission, the work being carried out by the Bureau of Mineral Resources.[26]

WORLD RESERVES

The domestic reserves of 66 million tons of ore on January 1, 1964, were depleted by 5.3 million tons by 1964 production, of which only 2.3 million tons was replaced by new development, leaving 63 million tons, average grade 0.24 percent U_3O_8, at the end of 1964. New Mexico and Wyoming accounted for 48 and 36 percent of the reserves, respectively, and 10 percent more was in Colorado and Utah, with the balance in Alaska, Arizona, California, Idaho, Montana, Nevada, North Dakota, Oregon, South Dakota, and Washington.

TABLE 8.—Free world uranium reserves December 31, 1964[1]

Country	Tons U_3O_8	Approximate grade percent U_3O_8
Canada	210,000	0.124
United States	152,000	.24
South Africa, Republic of	150,000	.02
France[2]	40,000	.14
India	12,000	.05–0.30
Australia	10,000	.26
Portugal	7,000	.2
Spain	6,000	.12–0.70
Others, including Argentina, Brazil, West Germany, Italy, Japan, Mexico, and Sweden	17,000	.02–0.15
Total	604,000	

[1] Estimated as recoverable at an average cost of \$8–\$10 per pound of U_3O_8.
[2] Including Malagasy Republic and Gabon.

The Canadian uranium reserves are the largest in the world, according to estimates presented at the Third International Conference on Peaceful Uses of Atomic Energy at Geneva, August 31–September 9, 1964. Reserves minable at U_3O_8 prices between \$5 and \$10 per pound are estimated to total 225 million tons of ore containing 207,000 tons of recoverable U_3O_8 and about 82,000 tons of ThO_2, 94 percent being in the Blind River-Elliot Lake area. Potential resources minable at U_3O_8 prices of less than \$20 per pound total about 1.1 million tons of U_3O_8 and 700,000 tons of ThO_2. A total of 63 million tons of ore containing 81,000 tons of U_3O_8 was mined and milled from 1953 through 1963. Peak annual production of nearly 16,000 tons of U_3O_8 was reached in 1959 when 25 mines and 19 mills were in operation.[27]

TECHNOLOGY

Research and development in nuclear science and engineering continued to grow at an accelerated rate as measured by the volume of literature published. Nuclear Science Abstracts[28] contained 45,203 items in 1964, compared with 42,247 in 1963 and 34,149 in 1962. The scope of fundamental research by AEC was reported.[29]

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[26] Mining Magazine (London). Australian Uranium. V. 110, No. 4, April 1964, pp. 279–283.

[27] Griffith, J. W., and S. M. Roscoe. Canadian Resources of Uranium and Thorium. Dept. Mines and Tech. Surveys, Min. Res. Div. (Ottawa, Canada). Miner. Inf. Bull. MR 77, 1964, 12 pp.

To meet the needs of industry for concise summaries of current atomic developments, the Technical Progress Reviews were prepared for and published by AEC. Issued quarterly, each of the reviews digested and evaluated the latest findings in five specific areas of nuclear technology and science.[30]

A detailed crystal-structure study was made of the torbernite minerals, including many phosphate and arsenate analogues. All exhibit the property of cation exchange. The structures were determined and refined by the new technique of three-dimensional least-square analysis, using X-ray diffraction and optical data. The waffle-like sheet structure of these minerals, previously hypothesized, was confirmed, and further details of the interlayer structure were revealed.[31]

Two methods of geochemical prospecting were developed and tested in Grand County, Utah. One involved the collection and analyses of juniper needles and leaves of shrubs; the other involved mapping and distribution of six indicator plants. After the plant studies were made, 1,268 holes were drilled to verify the presence of ore.[32]

The geology of uranium-bearing veins in the United States was the subject of a comprehensive six-part study. It included a list and a map showing the geographic distribution of uraniferous veins; discussed the geologic age of veins and the host rocks, the mineralogy, structural characteristics, and alteration; and concluded by discussing concepts of the origin. Each section is characterized by extensive lists of cited literature.[33] Another report describes uranium fissure-vein deposits of the Front Range in Colorado, which have yielded at least $6 million worth of ore.[34]

Geologic reports, each including numerous geologic maps, were published about three different areas of Wyoming;[35] while another paper described uranium deposits in another Wyoming area.[36] Other reports described important uranium deposits along the Utah-Arizona border[37] and the uraniferous sandstones around Edgemont, S. Dak.[38]

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[28] U.S. Atomic Energy Commission, Division of Technical Information. Nuclear Science Abstracts. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C., 20402. V. 18, Nos. 1–24, issued semimonthly, 1964, 6,075 pp.

[29] U.S. Atomic Energy Commission. Fundamental Nuclear Research. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C., 20402, December 1964, 299 pp.

[30] Baker, P. S., A. F. Ruff, and Associates (Oak Ridge National Laboratory). Isotopes and Radiation Technology. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C., 20402. V. 1, Nos. 1–4, 1964, 360 pp.

Cottrell, W. B., W. H. Jordan, and Associates (Oak Ridge National Laboratory). Nuclear Safety. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C., 20402. V. 5, Nos. 1–4, 1964, 429 pp.

Dayton, R. W., E. M. Simons, and Associates (Battelle Memorial Institute). Reactor Materials. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C., 20402. V. 7, Nos. 1–4, 1964, 282 pp.

Lawroski, Stephen, and Associates (Argonne National Laboratory). Reactor Fuel Processing. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C., 20402. V. 7, Nos. 1–4, 1964, 314 pp.

Zinn, W. H., and J. R. Dietrich (General Nuclear Engineering Corporation). Power Reactor Technology. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C., 20402. V. 7, Nos. 1–4, 1964, 441 pp.

[31] Ross, Malcolm, Howard T. Evans, Jr., and D. E. Applemen. Studies of the Torbernite Minerals. Am. Miner., v. 49, Nos. 11 and 12, November–December 1964, pp. 1578–1621.

[32] Cannon, Helen L. Geochemistry of Rocks and Related Soils and Vegetation in the Yellow Cat Area, Grand County, Utah. Geol. Survey Bull. 1176, 1964, 127 pp.

[33] Walker, George W., Frank W. Osterwald, and John W. Adams. Geology of Uranium-Bearing Veins in the Conterminous United States. Geol. Survey Prof. Paper 455–A–F, 1963, 120 pp.

[34] Sims, P. K., and D. M. Sheridan. Geology of Uranium Deposits in the Front Range, Colo. Geol. Survey Bull. 1159, 1964, 116 pp.

Western Nuclear, Inc., Jeffrey City, Wyo., described two methods of heap leaching that have been used to recover more than 400,000 pounds of U_3O_8 from low-grade or semiwaste uranium ores. In one method, a leach site about 400 feet square was prepared on a sloping area and lined with polyethylene sheeting. Perforated drainage pipes were laid in shallow ditches 18 feet apart. Low-grade ore averaging from 0.05 to 0.06 percent U_3O_8 and mostly minus 1-inch size was dumped onto the site by 15-ton dump trucks. After the pile was completed, it was leveled and divided into sections by dikes, and 35-percent sulfuric acid solution was run into the completed section. After about 30 days, uranium-bearing leach solution began to flow from the drain pipes, and this was collected and shipped 28 miles in tank trucks to the company Split Rock mill for recovery of the uranium. Average recovery was 75 percent.[39]

The second method used by Western Nuclear, Inc., was installed at the Spook property in Converse County, about 165 miles northeast of Jeffrey City. This employed percolation leaching in three concrete tanks 41 feet square by 11 feet deep. The ore, crushed to minus ¾-inch and containing 0.13 to 0.15 percent U_3O_8, was first agglomerated with sulfuric acid solution in a kiln-type tube 8 feet in diameter and 60 feet long. About 400 tons of agglomerated material was charged each day into one of the tanks, and solution was percolated upward to fill the tank, then recirculated downwards for 4 hours. The pregnant leach solution was removed, the uranium upgraded by liquid-solid ion exchange, and then precipitated with anhydrous ammonia. The resultant slurry containing about 11.2 percent U_3O_8 was shipped to the Split Rock mill for final recovery of the uranium. Average recovery was about 86 percent.

Rio Algom Mines, Ltd., in the Elliot Lake area, Canada, recovered uranium by a leaching-in-place method. Its Milliken mine, no longer producing ore, was kept dewatered with about 0.5 million gallons of water daily pumped to the ion-exchange section of the mill. In addition to normal drainage water, water poured into old stopes returned to the main pumping station and carried as much as 1.5 pounds of U_3O_8 per thousand gallons. Bacteria, known as thiobacillus ferrooxidans, appear to act as catalysts in the leaching process.[40] Stanrock

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[35] Sharp, W. N., E. J. McKay, F. A. McKeown, and A. M. White. Geology and Uranium Deposits of the Pumpkin Buttes Area of the Powder River Basin, Wyoming. Geol. Survey Bull. 1107–H, 1964, pp. 541–638.

Sharp, William N., and Anthony B. Gibbons. Geology and Uranium Deposits of the Southern Part of the Powder River Basin, Wyoming. Geol. Survey Bull. 1147–D, 1964, 60 pp.

Stephens, James G. Geology and Uranium Deposits at Crooks Gap, Fremont County, Wyoming. Geol. Survey Bull. 1147–F, 1964, 82 pp.

[36] Melin, Robert E. Description and Origin of Uranium Deposits in Shirley Basin, Wyoming. Econ. Geol., v. 59, No. 5, August 1964, pp. 835–849.

[37] Young, Robert G. Distribution of Uranium Deposits in the White Canyon-Monument Valley District, Utah-Arizona. Econ. Geol., v. 59, No. 5, August 1964, pp. 850–873.

[38] Ryan J. Donald. Geology of the Edgemont Quadrangle, Fall River County, South Dakota. Geol. Survey Bull. 1063–J, 1964, pp. 379–426.

[39] Mashbir, Don S. Heap Leaching of Low Grade Uranium Ore. Min. Cong. J., v. 50, No. 12, December 1964, pp. 50–54.

[40] Northern Miner (Toronto, Canada). Rio Algom Leaches Uranium From Inactive Mine. V. 50, No. 27, Sept. 24, 1964, pp. 1–2.

Uranium Mines, Ltd., at Quirke Lake practices a similar bacterial leaching operation which produces about 10,000 pounds of U_3O_8 per month. The extraction method consists of a high-pressure wash of stope walls and stope fill. Quirke Lake water, which is slightly acid ($pH=5.0$) is used.[41]

The Third International Conference on the Peaceful Uses of Atomic Energy was held in Geneva, Switzerland, from August 31 through September 9, 1964. As with the First (1955) and Second (1958) Conferences, practically every phase of the nuclear industry was discussed. A total of 748 papers from 38 countries and 5 international agencies was accepted for the Conference and more than 4,000 scientists from 75 nations attended. New data on ore reserves were presented, and significant progress was reported in fuel fabrication, breeder reactors, water desalination, and advanced reactor design, but most of the papers related to reactor applications and material problems. Nuclear power costs and the economic merits of water-cooled, gas-cooled, and heavy-water-moderated reactors were discussed in many papers.[42]

Laboratory research continued on electrolytic production of uranium metal directly from uranium dioxide (UO_2). Such a method would avoid the costly steps of converting UO_2 to uranium tetrafluoride, followed by the batch process of magnesium reduction to uranium metal. In the electrolytic process, UO_2 was dissolved in a bath of the fluorides of uranium, lithium, and barium. Electrolysis was conducted with carbon anodes and graphite cathodes at 1,200° C or more, above the melting point of uranium metal, which collected in a pool at the bottom of the cell. In previous work, the uranium metal was contaminated by undissolved oxide which prevented complete coalescence. An especially designed cell afforded complete coalesence of the metal and permitted direct feeding of UO_2.[43]

Commercial uranium metal was electrorefined in a laboratory cell, using molten-salt electrolysis in an inert-atmosphere cell. Low-melting-point electrolytes comprised of the chlorides either of lithium, potassium, and uranium or of sodium, potassium, and uranium were used. Electrolyses were conducted as low as 440° C and as high as 860° C. Uranium deposits were crystalline and varied from flaky to finely dendritic. The metal had to be leached and washed carefully to remove electrolyte salts, and this was best done in an argon atmosphere to prevent severe oxidation of the metal. Consolidated metal contained less than 30 parts per million of metallic impurities.[44]

Electrical conductivities and densities of fluoride systems of lithium and sodium with uranium and thorium were measured as functions of composition and temperature. The specific conductance and density varied linearly with temperature.[45] A rapid infrared absorbance technique was developed for analyzing anodic gases produced during the electrowinning of uranium and other metals from molten fluorides. Typical components analyzed are CO, CO_2, CF_4, C_2F_6, C_3F_8, COS, CS_2, and SiF_4. The procedure requires about 20 minutes for the principal gases and is used for cell control during electrolysis.[46]

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[41] Eldorado Mining and Refining Limited (Ottawa, Canada). Uranium in Canada. 1964, p. 120.

[42] Nucleonics. Nucleonics Reports on Geneva 1964. V. 22, No. 10, October 1964, pp. 6–125. U.S. Atomic Energy Commission. Atoms for Peace Conference 1964. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C., 20402, 1964, 112 pp.

[43] Kesterke, D. G., D. C. Fleck, and T. A. Henrie. Direct Electrolysis of Uranium Dioxide to Uranium Metal in Fluoride Melts. BuMines Rept. of Inv. 6436, 1964, 12 pp.

[44] Cattoir, F. R., and T. A. Sullivan. Molten-Salt Electrorefining of Uranium. BuMines Rept. of Inv. 6507, 1964, 26 pp.

[45] Brown, E. A., and Bernard Porter. Electrical Conductivity and Density of Molten Systems of Uranium Tetrafluoride and Thorium Fluoride with Alkali Fluorides. BuMines Rept. of Inv. 6500, 1964, 18 pp.

Uranium mononitride (UN) has great potential as a refractory nuclear fuel. Both UN and UC have higher thermal conductivity and uranium density than UO_2, and they offer higher burnup and operating temperatures than metallic fuels. UN also has better compatibility with some metals than UC and it exhibits no significant corrosion in air.[47]

The Hallam (Nebr.) Nuclear Power Facility, an 81-Mw sodium-graphite reactor power station and the first to produce superheated steam at 860° F and 825 psi, was described; operating experience from the startup in September 1963 through July 1964 was discussed.[48] Similar information was presented on the Big Rock Point (Mich.) Nuclear Power Plant, covering its first 2 years of operation. This is a 72-Mw, oxide-fueled, direct-cycle, forced-circulation, boiling-water reactor which has generated more than 330,000 Mw-hours of electricity from an output of a little more than 1 million Mw-hours of thermal energy.[49]

The Systems for Nuclear Auxiliary Power (SNAP) program has been described as the most challenging area in the nuclear field. Nuclear energy appears to be the only answer to power requirements in long-ranging sustained space flights, and research and development work continued in 1964 in many problem areas. A series of technical papers were published covering the following subjects: The Rankine Cycle utilizing liquid-metals, corrosion of high-temperature materials in alkali metals, heat transfer, power generation, and a description of Romashka, the Russian experimental space reactor.[50]

The U.K. Atomic Energy Authority claims that its huge installation at Windscale, England, is the largest nuclear-fuel reprocessing plant in the world and that the installation will take care of both British and overseas fuel reprocessing work for several decades. It is expected to provide a cheap source of fissile plutonium for the future enrichment of fast and thermal reactors. Irradiated fuel rods are first stored in a cooling pond for 150 days to permit the highly radioactive I^{131} (8.04-day half life) to disintegrate to a low level. The rods are decanned, and the fuel is dissolved in nitric acid, uranium and plutonium are extracted preferentially from the aqueous nitrate solution, using 20 percent tributyl phosphate (TBP) in kerosine. The organic product is stripped with a solution of nitric acid and ferrous sulfamate. The sulfamate reduces tetravalent plutonium to the trivalent plutonium which is unable to form strong complexes with TBP and, therefore, enters the aqueous phase, leaving the uranium in the organic phase.[51] A survey of the latest developments in nuclear-fuel reprocessing described all the active world plants and the many aqueous, volatility, and pyrometallurgical processes that have been developed. An excellent list of 45 references is included.[52]

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[46] Johnson, J. L., G. H. Cobb, and H. H. Heady. Infrared Analysis of Gases Produced During Molten Salt Electrolysis of Metals. BuMines Rept. of Inv. 6476, 1964, 11 pp.

[47] Bugl, J., and D. L. Keller. Uranium Mononitride—A New Reactor Fuel. Nucleonics, v. 22, No. 9, September 1964, pp. 66–70.

[48] Brown, Karl K. Operating Hallam. Nucleonics, v. 22, No. 9, September 1964, pp. 41–46.

[49] Haueter, R. L., L. M. Hausler, and R. B. DeWitt. Operating Big Rock Point. Nucleonics, v. 22, No. 11, November 1964, pp. 41–45.

[50] Nucleonics. Advanced Technology for Space Reactors. V. 22, No. 3, pt. 1, March 1964, pp. 33–48; v. 22, No. 6, pt. 2, June 1964, pp. 51–54; and v. 22, No. 12, pt. 3, December 1964, pp. 68–70.

Nuclear explosives can be used to move or to shatter large masses of rock, and AEC continued its Plowshare program for developing industrial and scientific uses for nuclear explosives. Project Hardhat, one of the experiments in the Plowshare series, was of particular interest because it was staged in granodiorite which is typical of rock found in many mining situations. A nuclear device equivalent to 5.4 kilotons of TNT was placed at a depth of about 940 feet and detonated. It was estimated that approximately 220,000 tons of rock was fractured initially and, if mining had continued, additional caving would have increased this tonnage.[53]

Another Plowshare experiment, known as Sedan, used a nuclear device equivalent to 100 kilotons of TNT buried 635 feet below the Nevada Test Site desert. A crater 600 feet in diameter and 320 feet in depth resulted, from which 7.5 million cubic yards of earth had been blown out by the explosion. Although exploded on July 6, 1962, additional data and an evaluation for mining purposes was made in 1964.[54]

Data from five Plowshare experimental underground nuclear explosions—Rainier, Logan, Blanca, Gnome, and Hardhat—were studied to determine the feasibility of using underground nuclear explosions to recover petroleum from reservoirs having low productivity. Production increases caused by fracturing of low-permeability reservoirs appear promising; however, increasing reservoir temperature with nuclear explosives showed dissappointingly small increases in production.[55]

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[51] Guccione, Eugene. Plutonium and Uranium Via Solvent Extraction From Nuclear Fuels. Chem. Eng., v. 70, No. 25, Dec. 7, 1964, pp. 148–150.

[52] Slansky, Cyril M. A Survey of Headend Processes for Nuclear Fuel Reprocessing. J. Metals, v. 16, No. 1, January 1964, pp. 25–32.

[53] Kabb, David D. Block Caving, Nuclear Style. Min. Eng., v. 16, No. 3, March 1964, pp. 48–52.

[54] Russell, Paul L. Stripping Overburden With Nuclear Explosives. Min. Eng., v. 16, No. 6, June 1964, pp. 76–80.

———. Stripping Overburden Using Nuclear Explosives. Society Min. Eng. Trans., v. 229, No. 2, June 1964, pp. 192–200.

[55] Atkinson, Charles H., and Robert T. Johansen. A Study of the Feasibility of Using Nuclear Explosions to Increase Petroleum Recovery. BuMines Rept. of Inv. 6494, 1964, 18 pp.

Watkins, J. Wade, and C. C. Anderson. Potential of Nuclear Explosives for Producing Hydrocarbons From Deposits of Oil, Natural Gas, Oil Shale, and Tar Sands in the United States. BuMines Inf. Circ. 8219, 1964, 17 pp.

Vanadium

By Gilbert L. DeHuff[1]

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CONSUMPTION of vanadium in 1964 in the United States showed an increase of more than 20 percent from the previous year. Domestic supply continued to exceed consumption, coming mostly from Colorado Plateau uranium operations but having a noticeable increase in that recovered from ferrophosphorus. Imports of ferrovanadium in 1964 were approximately the same as those for 1963, and imports of ore or concentrate were reported for the first time since 1960. Exports classified as ores, concentrates, oxides, and vanadates returned to a more normal level for recent years, being more than double those of 1963. Introduction of a new vanadium-carbon-iron alloy at a lower price than ferrovanadium received favorable response from the steel industry, resulting in lower prices for ferrovanadium.

TABLE 1.—Salient vanadium statistics

(Short tons of contained vanadium)

	1955–59 (average)	1960	1961	1962	1963	1964
United States:						
Production:						
Ore and concentrate:						
Recoverable vanadium[1]	3,519	4,971	5,343	5,211	3,853	4,362
Value .... thousands	W	$17,748	$19,076	$18,605	$13,756	$13,061
Vanadium pentoxide recovered	3,620	5,495	5,817	[r] 4,750	3,897	5,049
Consumption	1,918	2,016	2,015	2,314	2,906	3,550
Imports:						
Ferrovanadium (gross weight)	3	15	----------	88	[r] 442	466
Ore and concentrate	19	3	----------	----------	----------	111
Exports:						
Ferrovanadium and other vanadium alloying materials containing more than 6 percent vanadium (gross weight)	144	162	120	201	183	103
Vanadium ores, concentrates, oxides, and vanadates	833	3,690	2,081	1,021	536	1,231
World: Production	4,566	7,236	8,728	8,264	7,155	7,600

[r] Revised.
[W] Withheld to avoid disclosing individual company confidential data.
[1] Measured by receipts of uranium and vanadium ores and concentrates at mills plus vanadium recovered from ferrophosphorus derived from domestic phosphate rock.

DOMESTIC PRODUCTION

Recovery of vanadium from ferrophosphorus obtained as a byproduct of western elemental-phosphorus production increased from 1963. Most domestic vanadium production, however, continued to come from western uranium-vanadium and vanadium-uranium ores, emphasis being shifted to vanadium. The relatively small remaining production was obtained from oil residues, boiler scrapings, and other miscellaneous sources such as foreign chromium ores processed in the United States for production of chromium chemicals.

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[1] Commodity specialist, Division of Minerals.

Vanadium was recovered from uranium-vanadium and vanadium-uranium ores at four mills: American Metal Climax, Inc. (Climax Uranium Co.), Grand Junction, Colo.; Mines Development, Inc. (subsidiary of Susquehanna-Western, Inc.), Edgemont, S. Dak.; Union Carbide Corp., Rifle, Colo.; and Vanadium Corporation of America, Shiprock, N. Mex. Ores processed included purchased ores as well as those from company-owned mines. Intermediate products—vanadium-bearing sludges, liquors, or tailings—from other uranium mills, including the Uravan, Colo., mill of Union Carbide Corp., also were treated. In the latter half of the year, Union Carbide Corp. reactivated its vanadium mine near Rifle and prepared it for production early in 1965. This is the first mine to be operated essentially for the vanadium content of its ores since such mines were closed a decade or more ago in favor of mines with ores of higher uranium content.

Kermac Nuclear Fuels Corp. (subsidiary of Kerr-McGee Oil Industries, Inc.) at Soda Springs, Idaho, and Vitro Chemical Co. (an operating division of Vitro Corporation of America) at Salt Lake City, Utah, recovered vanadium from ferrophosphorus obtained as a byproduct from production of elemental phosphorus from Idaho phosphate rock. The Kermac ferrophosphorus came from the Soda Springs plant of Monsanto Company; Vitro obtained its supply from the Pocatello, Idaho, plant of FMC Corp.

Data in table 4 include all the vanadium pentoxide produced from the aforementioned sources—including that obtained from oil residues, boiler scrapings, chromium chemical production from imported chromite, and other miscellaneous sources.

Vanadium Ferroalloys.—Ferrovanadium was produced in the United State principally by Reading Alloys Co., Inc., Shieldalloy Corp., Union Carbide Corp., and Vanadium Corporation of America. Production decreased 20 percent from that reported for 1963, but total production of vanadium ferroalloys, including vanadium-carbon-iron alloys, increased appreciably.

Vanadium Metal.—Vanadium metal was produced by Oregon Metallurgical Corp., Union Carbide Corp., and Vanadium Corporation of America. Both high-purity metal and an alloying grade of 90-percent vanadium content were produced.

TABLE 2.—Recoverable vanadium of domestic origin produced in the United States, by States

(Short tons of contained vanadium)

State	1955–59 (average)	1960	1961	1962	1963	1964
Colorado	2,713	4,026	4,149	3,742	3,047	3,312
Utah	494	462	514	525	382	405
Arizona and other States [1]	312	483	680	944	424	645
Total	3,519	4,971	5,343	5,211	3,853	4,362

[1] Includes Idaho, 1961–64; Montana, 1957; New Mexico, 1956–64; South Dakota, 1960–64; Wyoming, 1956–58, 1960–64; Oregon, 1964.

TABLE 3.—Mine production and recoverable vanadium of domestic origin produced in the United States

(Short tons)

Year	Mine production [1]	Recoverable vanadium [2]	Year	Mine production [1]	Recoverable vanadium [2]
1955-59 (average)	6,514	3,519	1962	7,647	5,211
1960	8,047	4,971	1963	6,047	3,853
1961	6,359	5,343	1964	5,184	4,362

[1] Measured by receipts of uranium and vanadium ores and concentrates at mills, vanadium content.

[2] Recoverable vanadium contained in ores and concentrates of footnote 1, plus vanadium recovered from ferrophosphorus derived from domestic phosphate rock.

TABLE 4.—Production of vanadium pentoxide in the United States

(Short tons)

Year	Gross weight	V_2O_5 content	Year	Gross weight	V_2O_5 content
1955-59 (average)	7,198	6,464	1962	r 8,955	r 8,483
1960	10,767	9,812	1963	7,347	6,959
1961	10,796	10,387	1964	9,775	9,013

r Revised.

CONSUMPTION AND USES

Domestic consumption of vanadium contained in ferrovanadium, other vanadium alloys, metal, and chemicals increased 22 percent from 1963. Consumption of ferrovanadium (including other vanadium-carbon-iron alloys) increased 24 percent. This, also, was the percentage increase registered for vanadium consumption by the steel industry. Vanadium used for producing carbon steel increased 49 percent. As in both 1963 and 1962, the greatest consumption outside the steel industry was for nonferrous alloys. This use of vanadium increased 11 percent, while that for chemicals increased 23 percent. A new vanadium-carbon-iron alloy (see Technology section) was accepted by the steel industry for many applications in place of ferrovanadium.

Vanadium Corporation of America was constructing a new plant at Cambridge, Ohio, for completion in January 1965 to produce vanadium oxytrichloride for use as a catalyst in producing ethylene-propylene synthetic rubbers.

TABLE 5.—Vanadium consumed and in stock in the United States in 1964, by type of material

(Short tons of vanadium)

Type of materia	Stocks at consumer plants, Dec. 31, 1963	Consumption	Stocks at consumer plants, Dec. 31, 1964
Ferrovanadium [1]	313	2,863	603
Oxide	25	132	12
Ammonium metavanadate	34	147	28
Other [2]	79	408	100
Total	451	3,550	743

[1] Includes other vanadium-carbon-iron alloys.

[2] Consists principally of vanadium-aluminum alloy, and relatively small quantities of other vanadium alloys and vanadium metal.

TABLE 6.—Vanadium consumed in the United States in 1964, by uses

Use	Short tons	Use	Short tons
Steel:		Gray and malleable castings	26
High-speed	299	Nonferrous alloys [2]	332
Hot-work tool	124	Chemicals	171
Other tool	91	Other [3]	38
Stainless	35		
Other alloy [1]	2,066	Total	3,550
Carbon	368		

[1] Includes some vanadium used in high-speed or other tool steels not specified by reporting firms.
[2] Principally titanium-base alloys.
[3] Principally high-temperature alloys, welding rods, cutting and wear-resistant materials.

STOCKS

Consumer stocks of vanadium held in the form of metal, ferrovanadium, other vanadium alloys, and chemicals was 743 short tons at the end of 1964, an increase of 65 percent from the beginning of the year. Stocks of vanadium—as fused oxide, precipitated oxide, and the same vanadium products, held at the end of 1964 by producers of oxide, metavanadate, alloys, metal, and chemicals—were approximately 2,300 tons. This figure does not include vanadium contained in stocks of intermediates, sludges, and tailings held by oxide producers.

As of December 31, 1964, the national stockpile inventory was 7,865 tons of vanadium. Of this quantity, 1,001 tons was held as vanadium contained in ferrovanadium, and 6,864 tons was contained in vanadium pentoxide. In addition, the Atomic Energy Commission retained some fused-vanadium pentoxide it had acquired during its uranium purchase program.

PRICES

Domestic vanadium ore continued to be quoted at 31 cents per pound of contained vanadium pentoxide, nominal. A published price of $1.15 per pound of contained vanadium pentoxide for fused vanadium pentoxide, a technical grade, prevailed throughout the year, although some quotations of $1.25 per pound were carried for a time. Actual prices for large lots, however, were approximately 80 cents or slightly lower in the first half of the year, but strengthened in the second half to reach 95 cents by yearend.

Quotations for open-hearth, crucible, and primos grades of ferrovanadium, containing 50 to 55 percent vanadium, opened the year at $2.85 to $3.05 per pound of contained vanadium, depending on the particular grade. At the end of March the price became $2.50 for each of these grades, after having been quoted at $2.60 for a short time.

Carvan, the new vanadium-carbon-iron alloy, was priced at $2.17 per pound of contained vanadium, effective April 1. Vanadium metal of 90-percent purity continued to be quoted at $3.45 per pound in 100-pound lots.

FOREIGN TRADE

Imports of ore or concentrate, 222,667 pounds from Norway, were the first to be reported since 1960, and the first of any consequence since Peruvian shipments stopped in 1955. Those for 1964 had a vanadium pentoxide content of 41,130 pounds, valued at $9,344. Imports for consumption were identical with the general imports for this item. General imports of ferrovanadium in 1964 were approximately the same as those for 1963. Vanadium carbide imports, both general imports and imports for consumption, consisted of 152 pounds from West Germany; those of other vanadium compounds were 10 pounds, also from West Germany.

Exports classified as ores, concentrates, oxides, and vanadates were 2,461,000 pounds (vanadium content)—more than double those of 1963 but well below the high levels of 1960 and 1961. Ferrovanadium exports were only 206,000 pounds, gross weight.

TABLE 7.—U.S. imports of ferrovanadium, by countries

Country	General imports[1]				Imports for consumption[2]			
	1963[r]		1964		1963		1964	
	Gross weight (pounds)	Value	Gross weight (pounds)	Value	Gross weight (pounds)	Value	Gross weight (pounds)	Value
Austria	198,368	$242,968	583,497	$731,655	[r] 209,391	[r] $255,138	413,573	$491,058
Belgium-Luxembourg[3]	438,508	638,930	249,798	191,883	464,659	670,027	244,457	183,164
Germany, West	137,823	176,604	44,092	59,353	[r] 137,823	[r] 176,604	66,113	93,769
Italy			11,023	11,481				
Japan	110,069	126,632	44,092	50,507	[r] 74,292	[r] 84,928	65,134	72,660
Total[3]	884,768	1,185,134	932,502	1,044,879	[r] 886,165	[r] 1,186,697	789,277	840,651

[r] Revised.

[1] Comprises ferrovanadium received in United States; part for immediate consumption and remainder entering bonded warehouses.

[2] Comprises ferrovanadium received for immediate consumption plus material withdrawn from bonded warehouses.

[3] Reported figures for both general imports (110,980 pounds at $4,380) and imports for consumption for Belgium-Luxembourg for June 1964 are being questioned.

Source: Bureau of the Census.

TABLE 8.—U.S. exports of vanadium, by countries

(Pounds)

Destination	Ferrovanadium and other vanadium alloying materials containing more than 6 percent vanadium (gross weight)		Vanadium ore, concentrates, pentoxide, vanadic oxide, vanadium oxide, and vanadates (except chemically pure grade) (vanadium content)		Vanadium flue dust and other vanadium waste materials (vanadium content)
	1963	1964	1963	1964	1964 [1]
North America:					
Canada	317,041	133,189	21,106	44,235	---
Honduras	---	683	---	---	---
Mexico	2,682	44,624	11,487	1,232	---
Total	319,723	178,496	32,593	45,467	---
South America:					
Argentina	---	---	---	280	---
Brazil	---	---	12,712	---	---
Colombia	---	---	---	145	---
Peru	---	---	896	---	---
Venezuela	18,000	---	---	---	---
Total	18,000	---	13,608	425	---
Europe:					
Austria	---	---	98,219	313,689	---
Belgium-Luxembourg	10,089	---	252,300	1,379,925	---
Czechoslovakia	---	---	3,080	---	---
Denmark	---	---	---	2,680	---
France	1,600	---	110,515	---	---
Germany, West	16,251	7,354	6,451	30,296	1,467
Ireland	---	5,070	---	---	---
Netherlands	---	7,988	62,283	---	---
Spain	---	---	---	63,840	---
Switzerland	---	---	3,696	---	---
United Kingdom	628	6,149	455	86,634	---
Total	28,568	26,561	536,999	1,877,064	1,467
Asia:					
India	---	---	---	2,470	---
Japan	---	601	487,552	418,264	120,087
Philippines	---	---	---	115,248	---
Taiwan	---	---	742	2,031	---
Total	---	601	488,294	538,013	120,087
Oceania:					
Australia	---	585	81	224	---
New Zealand	---	---	242	---	---
Total	---	585	323	224	---
Grand total:					
Quantity	366,291	206,243	1,071,817	2,461,193	121,554
Value	$587,690	$308,880	$1,641,122	$3,619,654	$14,000

[1] No transactions in 1963.

Source: Bureau of the Census.

WORLD REVIEW

A shortage of vanadium was reported to have developed in Great Britain and Europe in 1964 with some resulting substitution by columbium.[2]

Canada.—A plant was constructed at the Montreal East refinery of Canadian Petrofina Ltd., for recovery of vanadium oxide from oil residues (see Technology section) at a rate of 810 pounds of vanadium pentoxide per day starting in January 1965. Operations on a shift basis could triple production.

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[2] Mining Journal (London). Tide Turns for Alloy Metals. V. 264, No. 6751, Jan. 8, 1965, pp. 7, 18.

Japan.—Highly ductile vanadium that can be cold-processed without annealing into rod, wire, or foil less than 10 microns thick, was developed by Showa Denko K. K. Plans called for commercial production at a rate of 1 ton per year to start about 1 year after completion of market studies. Price was expected to be $38 to $64 per pound, compared with $64 to $190 paid for imported metal. Welding of titanium to steel was among the expected applications.[3]

TABLE 9.—World production of vanadium in ores and concentrates, by countries[1]

(Short tons)

Country	1955–59 (average)	1960	1961	1962	1963	1964
North America: United States (recoverable vanadium)	3,519	4,971	5,343	5,211	3,853	4,362
South America:						
Argentina	2	NA	[e]4	9	[e]6	NA
Peru (eontent cf concentrate)	15	----	----	----	----	----
Europe: Finland	[2]330	625	701	629	771	[3]770
Africa:						
Angola	10	----	----	----	----	----
Zambia (recovered vanadium)	----	146	112	3	----	----
South Africa, Republic of	[3]215	656	1,423	1,393	1,391	1,282
South-West Africa (recoverable vanadium)	475	838	1,145	1,019	1,134	[e]1,165
World total (estimate)[1]	4,566	7,236	8,728	8,264	7,155	7,600

[e] Estimate. NA Not available.
[1] This table incorporates some revisions.
[2] Average annual production 1956–59.
[3] Average annual production 1957–59.

South Africa, Republic of.—Exports of fused vanadium pentoxide totaled 3,575 short tons in 1964, compared with 1,908 tons in 1963. Exports of ammonium metavanadate for the 2 years were, respectively, 67 and 27 tons. Transvaal Vanadium Co. (Pty) Ltd., a subsidiary of Anglo-American Corporation of South Africa, Ltd., was the only large vanadium producer in 1963 and 1964. Company production came from the Kennedy's Vale mine in northeastern Transvaal, approximately 30 miles northwest of Lydenburg. Federale Vanadium Mining Co., a subsidiary of Volkskas Bank, Ltd., operated a small experimental vanadium plant north of Pretoria from mid-1963 to the end of April 1964.[4] In September, announcement was made that Vanadium Corporation of America had signed a long-term agreement with Anglo American Corp. for a subsidiary of the latter, Highveld Development Co., Ltd., to supply vanadium-rich slag phased to anticipated reduction of Western United States vanadium operations.[5] The Highveld reserve of vanadiferous titaniferous magnetite ore was estimated to be 200 million tons readily accessible at surface, averaging 1.8 percent vanadium pentoxide content (4 billion pounds of vanadium). The ore reserve to reasonable mining depths was placed in excess of 500 million tons. The steel plant planned with recovery of vanadium as a coproduct would be at Witbank in the Transvaal.[6] An eventual annual production of 30 million pounds of vanadium pentoxide was given as a likely target to be achieved in stages. The first stage of production was expected to be reached in 1969 and to include vanadium pentoxide production, possibly at a rate of 18 million pounds per year.

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[3] Chemical Engineering. V. 71, No. 26, Dec. 21, 1964, p. 32.
[4] Bureau of Mines. Mineral Trade Notes. V. 59, No. 4, October 1964, p. 51.
Mining Journal (London). V. 262, No. 6708, Mar. 13, 1964, p. 205.
[5] Metal Bulletin (London). No. 4932, Sept. 22, 1964, p. 20.
Mining Journal (London). V. 263, No. 6736, Sept. 25, 1964, p. 233.

South-West Africa.—The only producer of vanadium in 1963 was the Berg Aukas mine of South West Africa Co., Ltd. Output of lead-vanadium concentrate was 11,250 short tons, close to that of 1961 and 11 percent more than 1962. Vanadium content of the ore decreases with depth—having a grade of 2 percent vanadium pentoxide in the upper levels above 500 feet, a little more than 1 percent below this to 810 feet, and about 0.6 percent at 1,000 feet. Two new levels at 660 and 810 feet were opened in 1964 by extension of the vertical shaft below 510 feet. An inclined shaft was completed to this level in 1963.[7] Long hole drilling was in general use at the mine in mid-1964, with diamond drills replacing percussion drills.[8]

United Kingdom.—As a result of research on the production of high-purity vanadium metal for use in advanced-design nuclear reactors, Magnesium Elektron, Ltd., built a unit at Manchester for production of vanadium chlorides. The high-purity metal, produced by reduction of vanadium trichloride with magnesium metal, has commercial uses for making magnetic and superconducting alloys. Further development of the process has resulted in commercial production of vanadium dichloride, vanadium tetrachloride, vanadium oxytrichloride, and high-purity anhydrous vanadium trichloride. The vanadium chlorides are important commercially as catalysts in production of copolymers such as the ethylene-propylene synthetic rubbers.[9]

TECHNOLOGY

The Bureau of Mines studied the isothermal recrystallization of electrorefined vanadium as a function of annealing time, temperature, and prior deformation. Hardness, metallographic, and X-ray techniques were used to determine recrystallization, and a recrystallization diagram was constructed. The activation energy for recrystallization was determined as 95,300 calories per mole for 60 percent reduction and 750° to 900° C annealing temperature. Activation energy for grain growth under the same conditions was 75,000 calories per mole. Recommended optimum metalworking schedule to produce a fine-grained structure with good physical properties in high-purity vanadium is cold-working to a reduction of 50 to 95 percent, followed by annealing at 850° to 1,050° C in an inert atmosphere.[10]

The effects of adding yttrium and rare-earth metals to electrorefined vanadium, melted to ingots in a nonconsumable electrode arc in helium atmosphere, was reported. Oxygen levels were reduced approximately 50 percent with a corresponding decrease in ultimate tensile strengths from 48,000 to 30,600 psi. Yield strengths were similarly lowered from 40,700 to 20,200 psi. These properties are comparable to those for iodide vanadium. The recrystallization temperature of cold worked electrorefined vanadium with yttrium and rare-earth additions was reduced from approximately 950° to 800° C. Maximum solubility of yttrium and most rare earth metals appears to be below 0.1 percent at both room and elevated temperatures.[11]

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[6] South African Mining and Engineering Journal (Johannesburg). V. 75, pt. 1, No. 3711, Mar. 20, 1964, p. 593.

[7] Bureau of Mines. Mineral Trade Notes. V. 60, No. 2, February 1965, p. 45.

[8] South African Mining and Engineering Journal (Johannesburg). V. 75, pt. 2, No. 3725, June 26, 1964, p. 191.

[9] Chemical Trade Journal & Chemical Engineer (London). V. 154, No. 4012, May 1, 1964, p. 617.

[10] Loria, E. A., W. D. Ludemann, and E. A. Rowe. Recrystallization of Vanadium. BuMines Rept. of Inv. 6547, 1964, 38 pp.

Ductile vanadium of from 99.5 to 99.8 percent purity can be prepared with metal recoveries exceeding 90 percent by employing bomb reduction of vanadium pentoxide with calcium. Yield and purity improved with increase in bomb size.[12]

A new steel addition agent containing 83 to 86 percent vanadium, 10.5 to 13 percent carbon, and 2 to 3 percent iron was announced by the Metals Division of Union Carbide Corp. after extensive testing. Having the trademark name Carvan, the material features lower cost, while giving equivalent vanadium recovery, dissolving time, and steel cleanliness as compared with ferrovanadium.

A new application for pure vanadium sheet or foil was developed for welding titanium metal to steel. A layer of vanadium is interposed between the other two metals before resistance welding, the resistance welding variables being calculated to preserve an unmelted interior core in the vanadium layer.[13]

In a process, jointly developed by Canadian Petrofina, Ltd., and the Canadian Department of Mines and Technical Surveys, vanadium pentoxide suitable for ferrovanadium production is recovered from Venezuelan crude oil. The crude oil is treated by fractionation, and the bottom residual (600 ppm vanadium) is processed to a fluid coke containing 4,000 ppm vanadium. The coke is burned as fuel for a boiler. The resulting ash (15 percent V_2O_5), recovered by electrostatic precipitation, is leached with sulfuric acid and filtered. The vanadium in the filtrate is oxidized by a small quantity of sodium chlorate, and it is precipitated as a hydrated pentoxide by adjusting the solution *p*H to 2 with ammonia. Nickel, also a constituent of the ash, remains in solution.[14]

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[11] O'Brien, W. L., and E. A. Rowe. Some Effects of Yttrium and Rare-Earth-Metal Additions on Electrorefined Vanadium. BuMines of Inv. 6553, 1964, 23 pp.

[12] Campbell, T. T., F. E. Block, and E. R. Andersen. Reducing Vanadium Compounds in Bomb Reactors. BuMines Rept. of Inv. 6374, 1964, 26 pp.

[13] South African Mining & Engineering Journal. V. 75, pt. 1, No. 3703, Jan. 24, 1964, p. 175.

[14] Canadian Department of Mines and Technical Surveys. Mines Memo 1963—Annual Review of Research Investigations of the Mines Branch. 1964, pp. 3, 34–35.
Canadian Chemical Processing. V. 48, No. 2, February 1964, pp. 5–6.
Chemical Engineering. V. 72, No. 5, Mar. 1, 1965, pp. 64–66.

Vermiculite

By Timothy C. May [1]

◆

APPROXIMATELY the same quantity of crude vermiculite was produced in 1964 as in 1963 although the value was 1 percent higher in 1964. The quantity of exfoliated vermiculite sold or used by producers in the United States was slightly higher in 1964 than 1963, but the total value was lower in 1964.

TABLE 1.—Vermiculite production and value statistics

	1955–59 (average)	1960	1961	1962	1963	1964
United States:						
Production:						
Crude………………thousand short tons..	196	199	206	205	226	226
Value………………thousand dollars..	$2, 731	$3, 108	$3, 350	$3, 293	$3, 572	$3, 613
Average value per ton………………	$13. 93	$15. 62	$16. 26	$16. 06	$15. 81	$15. 99
Exfoliated……………thousand short tons..	157	151	151	152	172	177
Value………………thousand dollars..	$9, 792	$10, 305	$10, 787	$11, 152	$13, 877	$13, 862
Average value per ton………………	$62. 37	$68. 25	$71. 44	$73. 37	$80. 68	$78. 32
World: Production crude……thousand short tons..	255	269	279	295	327	343

DOMESTIC PRODUCTION

Crude Vermiculite.—Four companies in three States produced crude vermiculite in 1964. The principal producer was W. R. Grace & Co., Zonolite Division, with operations in Lincoln County, Mont., and Laurens County, S.C. Patterson Vermiculite Co. and American Vermiculite Co., Laurens County, S.C., produced moderate amounts, and a small output was reported by Rimledge Uranium & Mining Corp., Custer County, Colo.

Exfoliated Vermiculite.—Twenty-six companies with 53 plants in 33 States exfoliated vermiculite in 1964. Florida had four exfoliating plants, with three plants in Illinois, Massachusetts, Minnesota, South Carolina, and Texas, and two plants in California, Mississippi, New Jersey, Oregon, and Pennsylvania. The remaining States had one exfoliating plant each.

CONSUMPTION AND USES

For the first time the consumption data provided by the exfoliaters of vermiculite was adequate to estimate the approximate percentages of their outputs for different purposes. Their excellent response has made possible compilation of the estimated use breakdown for the United States: Aggregates (concrete, plaster, cement) 41 percent; insulation (loose fill, block, pipe covering, packing) 35 percent; agriculture (horticulture, soil conditioning, fertilizer carrier, litter) 13 percent; and miscellaneous, 11 percent.

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[1] Commodity specialist, Division of Minerals.

PRICES

E&MJ Metal and Mineral Markets quoted nominal yearend prices for crude vermiculite as follows: Per short ton, f.o.b. mines, Montana and South Carolina, $9.50 to $18; and South Africa, c.i.f. Atlantic ports, $27.85 to $38.50.

FOREIGN TRADE

Imports of crude vermiculite from the Republic of South Africa were 28 percent higher than 1963. Crude vermiculite is imported duty free into the United States.

WORLD REVIEW

Canada.—Vermiculite was exfoliated by the following companies:

Company:	*Plant loation*
Grant Industries, Ltd	Vancouver, British Columbia.
Do	Calgary, Alberta.
Do	Regenia, Saskatchewan.
Do	Winnepeg, Manitoba.
F. Hyde & Co., Ltd	Montreal, Quebec.
Do	Toronto, Ontario.
Do	St. Thomas, Ontario.
Mid-West Expanded Ores Co., Ltd	St. Boniface, Manitoba.
Vantec Industries Ltd. (formerly Western Expanded Ores Ltd.)	Richmond, British Columbia.
Vermiculite Insulating Ltd	Lachine, Quebec.
Western Gypsum Products Ltd	Vancouver, British Columbia.

Crude vermiculite exfoliated in Canada was imported from the United States and the Transvaal, Republic of South Africa. The total vermiculite exfoliated in 1963 was about the same as 1962. In 1963 loose insulation consumed 80 percent of production. Plaster accounted for 12 percent, 5 percent was used in insulating concrete, and 3 percent was used in agriculture, horticulture, and underground pipe insulation. Vermiculite was marketed in bags of 3 and 4 cubic feet. Crude vermiculite was imported at costs ranging from about Can$25 to $60 per ton.[2]

It was reported that Olympus Mines, Stanleyville, Ontario, was constructing a vermiculite processing plant.

South Africa, Republic of.—Crude vermiculite was produced by The Transvaal Ore Co., Ltd., at Phalaborwa. The vermiculite deposits at Phalaborwa are among the world's largest, and practically all the vermiculite marketed in Europe comes from this source.

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[2] Wilson, S. H., Lightweight Aggregates, 1963 (Preliminary). Dept. Mines and Tech. Surveys, Ottawa, Canada, May 1964, 6 pp.

TABLE 2.—Free-world production of vermiculite by countries[1][2]

(Short tons)

Country[1]	1955–59 (average)	1960	1961	1962	1963	1964[p]
Argentina	659	349	541	2,962	1,532	3,348
India	236	17	697	410	746	466
Kenya	224	283	----------	22	101	31
Morocco	[3] 147	----------	----------	----------	----------	----------
South Africa, Republic of	57,106	69,022	71,118	85,534	98,758	111,872
Southern Rhodesia	219	----------	----------	----------	----------	----------
Sudan	[4] 132	----------	55	55	----------	----------
Tanzania	[4] 108	20	157	72	30	144
United Arab Republic (Egypt)[5]	133	121	85	313	33	459
United States (sold or used by producers)	195,560	199,072	206,637	205,749	226,278	226,299
Free world total[1][2]	254,524	268,884	279,290	295,117	327,478	342,619

[p] Preliminary.

[1] Vermiculite is produced in Brazil, but data are not available, and no estimate of production is included in the total.

[2] This table incorporates some revisions.

[3] One year only, as 1957 was the only year of commercial production.

[4] Average annual production 1958–59.

[5] Includes mica.

TABLE 3.—Republic of South Africa: Exports of crude vermiculite by countries[1]

(Short tons)

Destination	1963	1964
Australia	2,031	2,932
Belgium	794	1,442
Canada	4,839	2,879
Denmark	1,313	866
France	7,413	10,343
Germany, West	7,599	9,922
Italy	15,721	18,289
Japan	924	1,687
Netherlands	1,647	1,127
Spain	1,368	2,287
Sweden	585	587
United Kingdom	28,308	34,502
United States	14,337	18,417
Other countries	3,908	2,574
Total	90,787	107,854
Total value[2]	$1,723,365	$2,026,972
Average value	$18.68	$18.79

[1] This table incorporates some revisions.

[2] Converted to U.S. currency at the rate of 1 rand equals US$1.3948 (1963) and US$1.3909 (1964).

Source: Quarterly Information Circular on Minerals for the Republic of South Africa and the Territory of South-West Africa.

TECHNOLOGY

At the Vermiculite Institute annual meeting, reports and discussions covered masonry fill, fireproofing, plastering, accoustical plastic, horticultural uses, and new fire ratings.[3]

Reported occurrences of regular interstratification of chlorite with vermiculite, monmorillonite, or swelling chlorite have indicated an association of this mineral type with carbonate deposits.[4]

Reports indicate that thin sheets of vermiculite have been developed by chemically treating vermiculite crystals and then macerating in water. When the resulting dispersion is dried out on a smooth, flat surface, the crystals form a continuous flexible film which can be made of any thickness. Tests are in progress at the Australian Commonwealth Scientific and Research Organization's Division of Forests, on the fireproofing properties of these films when laminated in plywood during manufacture.[5]

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[3] Pit and Quarry. Vermiculite Institute Convention. V. 56, No. 11, May 1964, pp. 34, 42, 144.

[4] Johnson, L. J. Occurrence of Regularly Interstratified Chlorite-Vermiculite As a Weathering Product in a Soil. Am. Miner., v. 49, Nos. 5 and 6, 1964, pp. 556–572.

An updated booklet on fire-resistance ratings was issued by the Vermiculite Institute. The booklet contains over 50 construction drawings.[6]

A booklet issued by the W. R. Grace & Co. (Zonolite) covers the chemical and physical properties of vermiculite and its uses. Gradations, chemical composition, crystal structure, ion exchange characteristics, absorption, and capacity as a chemical carrier are described.[7]

Vermiculite is used for the building of emergency fire stoppings at the mines in Australia owned by the Zinc Corp., Ltd., and New Broken Hill Consolidated, Ltd. The vermiculite wall is built 2 feet thick and stability is achieved by crisscrossing alternate layers of bags. Vermiculite blocks also are used to build fire-stops.[8]

A patent was granted for the use of exfoliated vermiculite in the manufacture of composite insulating refractories.[9]

A process was patented for a wear-resistant material made of a mixture vermiculite and nickel for use in coating aluminum articles.[10]

A design for a vertical apparatus for exfoliating vermiculite was patented. The crude vermiculite is suspended in an upward stream of pressurized heated air. Suction is exerted at the top of the shaft to draw off the exfoliated material while leaving other particles suspended in the furnace.[11]

A patent was granted for the use of exfoliated vermiculite for the manufacture of a slow release medicament for combating bloat in cows. Monosodium dodecyl benzene sulfonate is adsorbed on exfoliated vermiculite which is then coated with ethyl cellulose.[12]

The use of exfoliated vermiculite in the manufacture of a vermin-resistant loose-fill insulation material was patented.[13]

The use of exfoliated vermiculite as one of the materials in a plaster composition for forming hard, even finishes on walls was patented.[14]

A process was patented for the use of exfoliated vermiculite in ingot molds to prevent the formation of surface layers containing deleterious metallic oxides and other nonmetallic inclusions.[15]

A patent was granted for the use of exfoliated vermiculite in sodium chlorate explosives for the purpose of absorbing some of the liquid fuel.[16]

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[5] South African Mining & Engineering Journal (Johannesburg). Vermiculite Films. V. 75, Part 1, No. 3704, 1964, p. 227.

[6] Vermiculite Institute. Vermiculite Fire-Resistance Ratings. Chicago, Ill., 1964, 14 pp.

[7] Grace & Co., W. R. (Zonolite Division). All About Vermiculite. Chicago, Ill., 1964, 12 pp.

[8] Mining & Minerals Engineering (London) Vermiculite in Mines. V. 1, No. 1, September 1964, p. 34.

[9] Kitano, S. Japanese Pat. 2243, Mar. 4, 1964.

[10] Borner, W. B. (assigned to International Nickel Co.). U.S. Pat. 3,132,927, May 12, 1964.

[11] Clute, F. H. Vacuum Expansion Exfoliator. U.S. Pat. 3,145,019, Aug. 18, 1964.

[12] Nichols, R. E. (assigned to Wisconsin Alumni Research Foundation). U.S. Pat. 3,119,738, Jan. 28, 1964.

[13] deLisle, A. L. (assigned to Phoenix Gems, Inc.). U.S. Pat. 3,149,030, Sept. 15, 1964.

[14] Tallentire, A. G., and C. Green (assigned to Imperial Chemical Industries, Ltd.). U.S. Pat. 3,153,196, Oct. 10, 1964.

[15] Turner, P. G. (assigned to Henry Wiggin & Co., Ltd.). British Pat. 968,943, Sept. 9, 1964.

[16] Cook, M. A., T. K. Collins, W. D. Pack, and N. L. Cook (assigned to Intermountain Research and Engineering Co., Inc.). Liquid Blanketed Chlorate Blasting Agent. U.S. Pat. 3,155,554, Nov. 3, 1964.

Water

By William H. Kerns [1]

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WATER supply problems related to stream pollution abatement, conservation of water (wise use and greater re-use), and development of new sources of water (desalination of sea and brackish water, greater regulation of streamflow or runoff, and weather modification) received increased attention during 1964 by individuals and industry and by city, county, State, United States, and foreign governments. This increased interest resulted from the realization that the population explosion and the growing need for water by each household and by industry have created an actual shortage of usable water in some areas and a forecasted shortage in many localities that could limit the economic growth and prosperity of an area or country if left unsolved.

Water supply potential for the contiguous United States in 1964, as measured by streamflow and by ground water levels, was generally below average. Extensive areas had deficient streamflow, while areas of excessive streamflow were scarce. In many regions of heavy pumping, ground water levels were at or near record lows. Great Lakes levels were below median range throughout the water year from October 1, 1963, to September 30, 1964.

LEGISLATION AND GOVERNMENT PROGRAMS

On July 2 the Water Resources Research Act of 1964 was passed by Congress, and on July 17 the Act was signed into law. On July 21 an announcement was made that the Office of Water Resources Research (OWRR) had been established by the U.S. Department of the Interior to administer the provisions of the Water Resources Research Act of 1964. This act was intended to stimulate, sponsor, provide for, and supplement present research programs on water resources and to train scientists in this field. OWRR is primarily concerned with authorizing grants to State water resources research centers for discovering new and improving old ways of dealing with water problems. By yearend 43 State water research centers or institutes had requested financial assistance for studies under this Act, and the first allotments of $75,000 each had been made to 14 States representing some of the major water problem areas of the Nation. Other grants will be made as additional funds become available.

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[1] Commodity specialist, Division of Minerals.

Also in the 88th Congress, efforts were made to pass laws to aid in preventing, controlling, and abating pollution of interstate waters by amending the Water Pollution Control Act of 1948, which was strengthened in 1956 and 1961, but none were successful.

In August President Johnson announced that the United States would be host to the First International Symposium on Water Desalination to be held October 3–9, 1965, in Washington, D.C. Invitations were extended to 114 governments to participate in this symposium, an international forum for the exchange of technical information on the economical conversion of sea and brackish water to fresh water. The symposium was being organized by the U.S. Department of the Interior and U.S. Department of State with the cooperation of the Agency for International Development and the United Nations Educational, Scientific, and Cultural Organization.

A United States-U.S.S.R. agreement to cooperate in desalination research, including use of nuclear power, was signed in Moscow in November. The agreement was similar to the informal understanding reached in Washington, D.C., in July that called for exchanges of scientific reports obtained from pilot and demonstration plants, joint symposia to discuss specific scientific and technical problems and projects, and reciprocal visits by technical experts to appropriate installations and laboratories.

The U.S. Department of the Interior, Office of Saline Water (OSW), continued its research and development programs throughout the year toward lowering the cost of producing fresh water from saline water.[2] Progress reports on selected OSW programs are given in the technology section.

Announcement was made in December that a contract had been signed for a study sponsored jointly by the Metropolitan Water District of Southern California, the U.S. Department of the Interior, and the U.S. Atomic Energy Commission for a dual-purpose electric power and water desalting plant. The study is to determine the feasibility of a dual-purpose plant with a fresh water capacity of between 50 and 150 million gallons per day (mgd) or enough for a population of 250,000 to 750,000 people, and an electric power capacity of 150,000 to 750,000 kilowatts, which would be marketed by the Metropolitan Water District to electric utilities in the region. In addition, it was announced that six $50,000 contracts had been awarded by the U.S. Department of the Interior for conceptual design studies for a water desalting and powerplant that would produce 50 mgd of water. Through these contracts the Government was marshalling the creativity and capabilities of American industry toward converting large quantities of sea water to fresh water at a low cost and an early date.

Several projects related to water, such as flood-control, deep-well pumping, and drainage-alleviation in the anthracite coalfields, were continued by the Bureau of Mines throughout the year. These programs have implemented Federal and State anti-stream-pollution activities, assisted in conserving natural resources, and enhanced the economy of the anthracite-producing region.

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[2] U.S. Department of the Interior, Office of Saline Water. Saline Water Conversion Report for 1964, January 1965, 279 pp.

Acid-mine drainage control research projects in bituminous coal mines were continued in cooperative studies with the Ohio River Valley Water Sanitation Commission and with the Public Health Service of the U.S. Department of Health, Education, and Welfare.

The Bureau of Mines continued to cooperate with other government agencies in preparing the comprehensive water development plans for all major U.S. river basins along the lines suggested by the Senate Select Committee on National Water Resources. Fundamental mine hydrology studies intended to develop methods, techniques, instruments, and engineering principles for defining mine drainage problems prior to development of underground mines and for controlling the drainage of water in mines were continued by the Bureau of Mines.

Through its Industrial Water Laboratory, the Bureau of Mines continued to provide consulting boiler-water service to requesting Federal agencies operating heating and powerplants. During the year, 13,738 samples of water, deposits, and chemicals were analyzed from about 10,000 boilers. These analyses were helpful in spotting and correcting corrosion problems in boilers and condensate return lines.

In the field of water supply and pollution control, major research activities supported by the Public Health Service of the U.S. Department of Health, Education, and Welfare were continued at an accelerated rate throughout the year. The research projects were both intramural, conducted within the Service, and extramural, performed in universities and other institutions with Federal aid.

DOMESTIC SUPPLY

The water supply for the Nation is based largely on precipitation. Deficient summer and autumn rainfall resulted in periods of severe to extreme drought in northeastern areas from northern Virginia through southern New England, in parts of Indiana and Illinois, and a Great Plains belt extending from southern Wyoming and the Nebraska Panhandle through western Texas. Other weather conditions that affected the water supply were a heavy snowfall in the western mountains, flood-producing rains in the Ohio River basin in March and in the Pacific Northwest in December, record breaking annual rainfall in the Southwest, and four hurricanes that were responsible for much rainfall in the Southeast.

During the water year of 1964, October 1, 1963, to September 30, 1964, the dominant features of the annual runoff pattern, a convenient measure of the water supply potential or manageable supply, were the extensive areas of deficient streamflow and the scarcity of areas of excessive streamflow. The deficient areas formed a broad and irregular, though not continuous, diagonal from southern California to central New England, and dipped down to the Gulf of Mexico. Except for small areas in Montana, Wyoming, and Arizona, flow was excessive only in the Southeast—in Georgia, South Carolina, and parts of adjacent States. Ground water levels at the end of the water year of 1964 were generally below average, but in Minnesota, North Dakota, Wyoming, and parts of Iowa, Nebraska, and Missouri ground water levels were above average. In many areas of heavy pumping, ground water levels were at or near record lows. Great Lakes levels were below average throughout the year and were increasingly deficient as the year progressed. Levels of Lake Superior were least deficient and those of Lakes Michigan and Huron most deficient.[3]

A report was published[4] on the water systems serving the 100 largest U.S. cities and supplying 60 million people. Of this total population served, about 56 percent received filtered water, 98 percent received water that had been chlorinated, and 34 cities serving 21 million people received fluoridated water. More than one-half of the cities got their water from surface sources, while 20 relied on ground water and 14 on combined ground and surface water.

Reports on the mineral and water resources of six States, Alaska, Colorado, Idaho, Nevada, South Dakota, and Utah, were published as Committee Prints for the Committee on Interior and Insular Affairs, U.S. Senate, in 1964. These reports, following the format of a publication for Montana in 1963, give detailed data for the water situation in each State, surface and ground water supply, utilization and storage, waterpower, and selected references. Similar reports for other States are being prepared.

An atlas of the chemical quality of public water supplies of the United States and Puerto Rico, 1962, was published[5] by the Geological Survey, U.S. Department of the Interior. Municipal water systems furnish water for commercial and industrial uses as well as for domestic uses. The atlas compares on a State-by-State average basis such qualities as hardness of water, fluoride and sodium content, and amounts of dissolved solids. The authors studied 1,596 municipal water supplies, serving 103 million people, in the preparation of this water quality atlas.

Two new preliminary maps, which provide detailed information on mineralized ground water resources of the contiguous 48 States, were released for open file inspection by the Geological Survey, U.S. Department of the Interior. The maps show areas underlain by mineral-bearing waters, locations and yields of representative wells and springs, and locations of about 25 Federal, industrial, and municipal desalinization plants. As the demand for fresh ground water increasingly approaches the full capacity of available supplies, especially in certain parts of the country, the need to develop mineralized water resources will grow rapidly. Therefore, the maps are expected to be extremely useful to planners concerned with water supplies for the future.

The mining industry of the Coeur d'Alene mining district, Idaho, played a leading role in establishing a program to combat the pollution of the South Fork of the Coeur d'Alene River into which slimes and tailings have been discharged since the first days of mining in the area. Mining companies in the district outlined plans to alleviate the pollution problem that are in accordance with the Idaho State Board regulations. These plans are to be fulfilled by the fall of 1967.

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[3] Geological Survey (in collaboration with Canada Department of Northern Affairs and National Resources). Water Resources Review: Nov. 1, 1964. Pt. 2, Summary for the 12 months, Oct. 1, 1963, to Sept. 30, 1964. Nov. 1, 1964, pp. 10–17.

[4] Durfor, Charles N., and Edith Becker. Public Water Supplies of the 100 Largest Cities in the United States, 1962. U.S. Geol. Survey Water-Supply Paper 1812, 1964, 364 pp.

[5] Durfor, Charles N., and Edith Becker. Chemical Quality of Public Water Supplies of the United States and Puerto Rico, 1962. Geol. Survey Hydrologic Investigations Atlas HA-200, 1964, 1 p.

CONSUMPTION AND USES

Water uses are classed as withdrawal and nonwithdrawal, and consumptive and nonconsumptive. Domestic, municipal, irrigation, waterpower, and industrial uses are classed as withdrawal uses, because the water must be pumped from the ground or diverted from a stream, lake, or reservoir. Navigation, waste disposal, recreation, and conservation of wildlife are nonwithdrawal uses. Water that is evaporated or incorporated in a product is consumed and classed as consumptive.

Total withdrawal of water in 1964 was estimated to exceed 340 billion gallons daily (bgd), compared with 135 bgd in 1940 and 40 bgd in 1900. Based on a total water supply of 1,200 bgd, the average runoff of all streams, the withdrawal in 1964 was nearly 30 percent of the potential supply.

Not all of the water withdrawn is consumed because much of it is returned to the streams or ground and can be reused many times if steps are taken to maintain its quality. Consumption of water for various uses ranges from 50 to 60 percent of the water withdrawn for irrigation down to 1 percent for steam-electric power cooling. In 1960, including water conveyance losses but excluding water used for water power, 40 percent of the total water withdrawal was used for irrigation, 51 percent for self-supplied industrial users, and the remaining 9 percent for rural and municipal (public supplies) domestic users.

Bureau of Mines experimental work and research on using water to mine both pitching and flatlying bituminous coalbeds and to transport coal were continued throughout the year. A progress report of the Bureau's hydraulic mining research since 1958 was published.[6] The Bureau also conducted studies to develop the design principles for using water to emplace backfill in mines as a means for ground support.

Exploration and development on the use of natural steam for electric power generation has been extensive in the Western United States where the potential for geothermal power exists. An economic evaluation of geothermal power was published[7] by the Bureau of Mines. A geothermal plant can produce electric energy for 6.70 mills per kilowatt-hour, compared with 6.96 for coal, 6.74 for oil, and 7.04 for gas.

Estimates of potential waterpower and historical data on waterpower developments in various parts of the world were assembled in a report[8] published by the Federal Geological Survey. Salient characteristics of the period studied, 1955–62, include increased use of the underground powerhouse, multiple-purpose developments and use of storage (including pumped storage) to increase the value of waterpower for peaking purposes. High-voltage long-distance transmission has been improved, and generating facilities tend to be larger than ever before.

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[6] Palowitch, E. R., and W. T. Malenka. Hydraulic Mining Research—A Progress Report. Min. Cong. J., v. 50, No. 9, September 1964, pp. 66–73.

[7] Kaufman, Alvin. Geothermal Power. An Economic Evaluation. BuMines Inf. Circ. 8230, 1964, 24 pp.

[8] Young, Loyd L. Summary of Developed and Potential Waterpower of the United States and Other Countries of the World, 1955–62. Geol. Survey Circ. 483, 1964, 38 pp.

Sticky water which does not run off buildings may help firemen keep fires from spreading to adjoining premises. The water is made sticky by a synthetic polymeric material in powder form developed by The Dow Chemical Co. It is pumped into the stream of water that is directed at the fire and converts the water into a gel, which builds up a layer as much as one-half inch thick. This layer, sticking to vertical walls or roofs, will absorb large amounts of radiant heat, protecting flammable material beneath it. It is reported to be useful in halting the spread of brush and forest fires.

Heavy water sales to U.S. customers totaled 6,102 pounds in 1964, compared with 4,000 pounds in 1963. Foreign shipments (sales) during the year totaled 63 tons, compared with 52.2 tons in 1963. All of the heavy water was produced by the U.S. Atomic Energy Commission (AEC) at its Savannah River plant, Aiken, S.C., which also provided heavy water reprocessing services for foreign and domestic users.[9]

The AEC Heavy Water Components Test Reactor at the Savannah River plant, which has been operating since 1962 testing fuel elements and components for pressurized heavy water-cooled, heavy water-moderated reactor systems, was shut down on December 1 and will be placed in a standby condition by the end of February 1965. This was occasioned by a redirection of the heavy water-moderated reactor program toward an organic-cooled rather than a heavy water-cooled system, and the Savannah plant could not contribute to the development of this system without major modifications.[10]

In August, Deuterium of Canada, Ltd., joint subsidiary of Deuterium Corp. (New York, N.Y.) and Industrial Estates, Ltd. (Halifax, Nova Scotia), started construction of a heavy water plant at Glace Bay, Nova Scotia, estimated to cost $30 million. Present specifications call for initial capacity of 200 tons per year, but Deuterium Corp. officials indicated that the capacity would be doubled if the Toronto, Canada, nuclear project were approved.[11] The company envisions shipping heavy water in 500-pound-capacity stainless steel drums to virtually any part of the world. Nuclear power projects similar to the one at Toronto—based on natural uranium reactors with heavy hydrogen (contained in heavy water) as a moderator—are blueprinted for France, Germany, India, Sweden, and the United Kingdom.

PRICES

Rates for water purchased from public and private water utilities varied widely. The typical small consumer such as a home owner may pay from 20 cents to 75 cents per 1,000 gallons, but the national average is 35 cents or about 2 cents per day per person. The range of prices for irrigation water is much greater, from less than 1 cent per 1,000 gallons where streamflow is ample, up to 20 cents or more in southern California's citrus groves; however, water delivered to the farmer generally ranges from ½ cent to 5 cents per 1,000 gallons. Costs for water in substantial quantities for industrial use, including pumping, treatment, and distribution, range from 1 cent to 15 cents per 1,000 gallons. The current cost of converting sea water to fresh water was reported to range from $1 to $1.50 per 1,000 gallons, compared with $4 to $5 in 1952 when the OSW program began.

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[9] U.S. Atomic Energy Commission. Annual Report to Congress of the Atomic Energy Commission for 1964. January 1965, p. 50.

[10] U.S. Atomic Energy Commission. Annual Report to Congress of the Atomic Energy Commission for 1964. January 1965, p. 103.

[11] Chemical Week. Doubling a Market. V. 95, No. 8, Aug. 22, 1964, p. 45.

WORLD REVIEW

NORTH AMERICA

Mexico.—Mexico City had water problems unlike those of any other city in the world. Ground water reserves under the city were more than ample for its needs. But for years this water has been tapped by more than 2,000 wells, and heavy pumping of water caused land subsidence of up to 2 feet per year. As the city sank, existing gravity-flow storm sewers became useless, and rainwater had to be pumped out of the city. In 1964 the second stage of a system of tunnels, canals, and pipelines that collect storm water and carry it out of the city by gravity was completed. The system discharges into a natural basin called Zumpango Lagoon, which has a capacity of 8,108 acre-feet, but will eventually be enlarged to hold 80,000 acre-feet. Plans have been made to use this water to irrigate 300,000 acres of farmland in the nearby Mezquital region.[12]

Nicaragua.—Managua, capital of Nicaragua, has utilized a unique natural water supply from the cup of a sunken volcano 5 miles from the city. The clear water from the deep volcano lake is transported to the city by pipelines.

West Indies.—Westinghouse Electric International Co. was awarded a $2.6 million contract for manufacturing and installing a desalination and power plant for St. Thomas, Virgin Islands. The combination plant was designed for producting 1 million gallons of fresh water from sea water and 7,500 kilowatts of electricity per day. Westinghouse estimated the cost of water conversion at about $0.90 per 1,000 gallons. Much of the island's water supply has been brought by barge from Puerto Rico at $1.45 per 1,000 gallons.[13]

EUROPE

The water problems in Europe were described.[14] It was concluded that Europe, while starting to appreciate its water problems, has made little progress toward a practical solution. There must be full acceptance of the fact that water is as vital a factor in industrial achievement and development as are labor, raw material, and technical skills.

France.—The building of a heavy water plant at Mazingarbe, near Bethune, the first such large-scale unit in France, was authorized by the French Government. Construction will take about 3 years. The

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[12] Engineering News-Record. Mexico City Drains Storm Water. V. 173, No. 17, Oct. 22, 1964, pp. 28–29.

[13] Chemical & Engineering News. V. 42, No. 45, Nov. 9, 1964, p. 53.

[14] Jackson, C. J. The Problem of Water in Europe. Chemistry & Industry (London), No. 34, Aug. 22, 1964, pp. 1468–1474.

Houillères du Nord et du Pas-de-Calais process, which is based on the principle of a hydrogen ion—ammonium ion exchange, will be used.

ASIA

Hong Kong.—Hong Kong completed its plans and let contracts to convert the 2,750-acre salt water Plover Cove into a fresh water lake to provide the Crown Colony with an adequate year-round water supply. The Government planned to construct three dams across the narrow-mouthed cove, located in the colony's New Territories north of Kowloon and Victoria Island. Salt water will be pumped out of the enclosed area and fresh water pumped in to create the lake. Although the reservoir will store 39 billion gallons of fresh water, only about 30 billion gallons will be available for distribution. This water supply will more than triple the present capacity in the colony.[15]

Philippines.—The World Bank lent $20.2 million to the National Waterworks and Sewerage Authority of the Philippines to expand and improve the water supply system of Manila and its suburbs. The project will take advantage of new water sources created by the Angat multipurpose dam. The new works will increase present water supply by about 200 mgd and was scheduled for completion in about 3 years, at a total estimated cost of $48.2 million.[16]

South Viet-Nam.—A water-treatment plant to supply fresh water to the 2 million residents of metropolitan Saigon will be built as a result of an Agency for International Development (AID) loan. Water for the $10 million treatment plant will be drawn from the Dong Nhai River. The plant will have a fresh water capacity of 130 mgd and will be built on the west bank of the river opposite the city of Bien Hoa, about 12 miles from Saigon. The water-treatment plant will include chemical feeding tanks, rapid sand filters, treated water reservoirs, and pumping stations, and is scheduled for completion early in 1966.[17]

AFRICA

Canary Islands.—A plant scheduled to be in operation in 1 year was begun in April to convert sea water into fresh water for human consumption as well as for agricultural and industrial applications. The system, a combined power generating and sea water conversion plant, will consist of a flash evaporator capable of producing 650,000 gallons of fresh water per day and two 750 kilowatt turbine generators together with associated switchgear transformers and a motor control center. Exhaust steam from the turbines will be used as a heat source for the evaporator converting sea water. The combination plant will be established on the island of Lazarote, off the northwest coast of Africa.[18]

Ghana.—The pride of Ghana, Akosombo Dam, backing up waters of the Volta River has started to form what will be the fourth largest reservoir in the world.[19] Since the middle of May, when filling began, water level at the dam had risen 50 feet in 2 months, and the modest vanguard of 120-million-acre-foot Lake Volta has begun to flood 3,275 square miles of the west African country. Ultimate powerhouse capacity will be 786,000 kilowatts. First power is due in September 1965.

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[15] Engineering News-Record. Hong Kong Stores Water in Sea. V. 172, No. 2, Jan. 9, 1964, pp. 26–28.

[16] International Commerce. Philippines Gets $20 Million for Manila Water System. V. 70, No. 32, Aug. 10, 1964, p. 14.

[17] International Commerce. Vietnam Gets Loan to Construct Plant for Water Treatment. V. 70, No. 3, Jan. 20, 1964, p. 16.

[18] South African Mining & Engineering Journal (Johannesburg). Flash Distillation for Fresh Water. V. 75, Pt. 1, No. 3714, Apr. 10, 1964, p. 789.

South Africa, Republic of.—The 293-foot-high Josini Dam under construction on Pongola River in northern Natal will be South Africa's largest dam when completed in 1967.[20] This title will last only until South Africa has constructed its proposed 390-foot-high Ruitge Valley and 395-foot-high van der Kloof dams in the big Orange River Scheme. Josini Dam was the key project in the $53 million Makatini Flats Irrigation Scheme that has been planned to develop 170,000 acres of farmland in the Zululand region.

TECHNOLOGY

The Office of Saline Water (OSW) continued basic research, process development, and demonstration plant projects to discover and develop economical ways and means to convert saline water to fresh water.[21] All of the basic research work was conducted by contract with other Federal agencies and with universities, private organizations, and industrial firms. Using this technique, the OSW has been able to use some of the finest scientists in the Nation to work toward solving the difficult technological problems involved in the development of new or improved conversion processes.

In its process development or applied research activities, the OSW has the responsibility of translating research data and results into bench-scale equipment, pilot units, and complete pilot plants. Most of the pilot plants for conversion of sea water to fresh water are being constructed at the OSW Research and Development Test Station at Wrightsville Beach, N.C. These plants include a 37,000-gpd plant to develop a thin-film distillation system, and a 15,000-gpd plant to develop further a freezing process based upon forming larger-size ice crystals.

In midyear an OSW contract was awarded to the FMC Corporation of San Jose, Calif., for the design and construction of a saline water conversion pilot plant at the OSW Research and Development Station at Wrightsville Beach, N.C. Completion of the design was expected by yearend. The pilot plant will utilize the vapor reheat distillation process and a radically new liquid-liquid heat exchanger system as a method for converting salt water to fresh water. The primary objective of the new process is to avoid the inherent disadvantages of scaling and high thermal barrier usually associated with metallic heat transfer surfaces. The liquid-liquid heat exchangers will eliminate any direct contact between the hot sea water and the metallic surface of a boiler or conventional heat exchanger. In the new pilot plant, bubbles of very hot oil enter the chamber containing the sea water and heat the water as they float upward through the chamber.

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[19] Engineering News-Record. Ghana's Akosombo Dam Has Volta River in Harness. V. 173, No. 5, July 30, 1964, pp. 26–28.

[20] Engineering News-Record. Josini Dam Will Water Zululand. V. 173, No. 19, Nov. 5, 1964, pp. 36–41.

[21] U.S. Department of the Interior, Office of Saline Water. Saline Water Conversion Report for 1964, January 1965, 279 pp.

In August under an OSW contract, W.R. Grace and Co., utilizing a chemical process, started producing descaled sea water in its saline water conversion pilot plant at Wrightsville Beach, N.C. Descaled water is water that has been freed of scale-forming substances that tend to gather on desalting equipment and that cause loss of efficiency. If descaled water can be used as feed to a distillation process desalting plant, higher temperatures can be used which would improve both efficiency and capacity. In addition, the elimination of acids, now used for partial control of scale formation, would effect economies through use of less expensive construction materials. At the same time, the Grace plant is expected to produce highly concentrated brines that might make recovery of byproducts from brines economically feasible and thus reduce the net cost of the descaled water.

Nearing completion at the close of the year is a 20,000-gpd hydrate pilot plant built by Sweet Water Development Co., Dallas, Tex., at the OSW Research and Development Test Station, Wrightsville Beach, N.C. The new chemical process, which uses a combination of temperature, pressure, and propane gas to produce fresh water from sea water, was demonstrated in a smaller, 700-gpd unit at St. Louis, Mo., in 1963. In the hydrate process, the hydrate crystals are formed by a chemical reaction between propane and water at temperatures above the freezing point of water. The hydrate crystals are then separated from the brine, washed, and decomposed to form salt-free water. The propane released when the crystals are decomposed is recycled to form more crystals. The pilot plant is expected to provide data for an economic appraisal of the process in comparison with other desalting systems.

Five demonstration plants completed by OSW, their locations, processes utilized, and fresh water capacities are as follows:

Area	Location	Process	Capacity (mgd)
Gulf coast	Freeport, Tex	Long-tube vertical multi-effect distillation.	1
West coast	San Diego, Calif. (moved to Naval Base, Guantanamo Bay, Cuba).	Multistage flash distillation	1
Northern Great Plains	Webster, S. Dak	Electrodialysis (membrane process).	.25
Arid areas of the southwest	Roswell, N. Mex	Forced-circulation vapor-compression.	1
East coast	Wrightsville Beach, N.C	Freezing	1

The plants were designed, built, and operated to demonstrate the reliability, engineering, operating, and economic potentials of the sea or brackish water conversion processes. Data obtained from the operation of the plants are evaluated to form the basis for the design of larger and more efficient plants.

During the latter half of the year, Fluor Corp. of Los Angeles, Calif., was preparing architectural and engineering designs, specifications, and drawings for a saline water conversion demonstration plant using a multistage-multieffect flash distillation process under an OSW contract awarded on June 11. The plant (Point Loma II) is to be erected on Point Loma near San Diego, Calif., to replace the demonstration plant (Point Loma I) recently dismantled and shipped to Cuba as a part of the Government program to make the naval base at Guantanamo Bay self-sufficient. Fluor is expected to develop for OSW conceptual design for a 50-mgd plant, optimized for fuel costs, electrical costs, and site conditions. It shall then prepare a design for a 1-mgd plant, which will incorporate, to the extent possible, critical design criteria from the larger plant. Under the terms of the contract, Fluor was to complete the plans and specifications on September 22. The California Department of Water Resources shared in the cost of Point Loma I plant and is participating in the replacement project. The City of San Diego purchased the water produced by the original conversion plant and will also buy water from Point Loma II plant when built.

A bibliography [22] was published listing monographs, scientific and technical reports, papers, and periodical articles that are the result of OSW sponsorship on saline water conversion investigations.

The United Nations Secretariat, under its program for water resources development, conducted a survey [23] of the economic and technical aspects of water desalination in developing countries as a part of its effort to promote and assist these countries toward self-sustaining growth. Although this survey showed that the known processes yield an expensive product, it revealed many interesting possibilities of application even at present costs.

The studies and research projects on the recovery of minerals from sea water have assumed new importance as a possible means of reducing the cost of saline water conversion. A very large number of processes have been proposed, ranging from those prompted by man's never-ending search for gold to those of more immediately practical aspect such as fertilizer production. The many proposed or tested methods for recovering minerals from sea water were described and evaluated.[24]

A continuing pilot study of water pollution from coal mine acid drainage was conducted jointly by agencies of the U.S. Department of the Interior; U.S. Department of Health, Education, and Welfare; and the State of West Virginia. A 35-square-mile demonstration site was selected. This site includes all of the two small watersheds draining into the Tygart River at Norton, near Elkins, W. Va., and contains three small active underground coal mines and a number of abandoned underground and surface mining operations. The first phase of the study, consisting of special aerial photography and mapping of the site, was completed during the year. On July 28 a contract for exploratory core and churn drilling was awarded to obtain samples of subsoil and rock from key spots in the Roaring Creek and Grassy Run watersheds within the Elkins demonstration site. From the samples the geology and hydrology of the area and the kind and degree of stream pollution now traceable to acid drainage from mines will be determined. Similar samples will be taken and analyzed at varying periods after each type of control method is put into effect to determine the relative efficiency of each method. Restoration of strip-mined areas to prevent surface drainage from entering underground mine openings, evaluation of the effectiveness of mine sealing, and reconstruction of gob piles to prevent formation of acid from surface drainage are among the control methods to be evaluated in the study.

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[22] U.S. Department of the Interior, Office of Saline Water. A Bibliography of Literature Resulting From the Activities Sponsored by the Office of Saline Water. Res. and Dev. Progress Rept. 82, October 1963, 59 pp.; U.S. Dept. of Commerce, Office of Tech. Serv., PB 181546.

[23] United Nations. Water Desalination in Developing Countries. Dept. of Econ. and Social Affairs, New York, 1964. 325 pp.

[24] Tallmadge, J. A., J. B. Butt, and Herman J. Solomon. Minerals From Sea Salt. Ind. and Eng. Chem., v. 56, No. 7, July 1964, pp. 45–65.

Contamination of surface waters by industrial and municipal wastes is a critical national problem. Since 1950 an increasing number of companies have disposed of toxic organic and inorganic industrial wastes into subsurface formations because the waste was odoriferous or highly toxic. In a Bureau of Mines study[25] of subsurface disposal of industrial wastes in the United States, it was found that subsurface injection is the most economical solution for many difficult disposal problems, but it is not the solution to every waste problem.

Estimates have been made that in the arid and semiarid regions of the Western States phreatophytes waste more than 25 million acre-feet of water annually. To reduce this nonbeneficial consumptive use of water, research studies are continuing. Methods to reduce this consumptive waste of water include: (1) Taking the plants away from the water, (2) taking the water away from the plants, and (3) substituting plants of higher beneficial use in the project area. U.S. Geological Survey Circular 413, "Phreatophyte Research in Western United States, October 1958 to March 1959," was updated to July 1964.[26]

Laboratory and field tests by the Bureau of Mines showed that using sodium tripolyphosphate (STP) in the injection water in waterflooding for secondary recovery of petroleum either eliminated or reduced the formation of precipitates, which are gradual accumulations of insoluble materials on the sandface.[27] This plugging material, composed primarily of insoluble precipitates of calcium, iron, and magnesium, has caused the injection pressures to increase while decreasing the amount of water injected.

Several hundred membrane-filter tests were made as part of a program to develop equipment and procedures to evaluate the quality of waters and to determine the quality of water suitable to efficiently flood oil sands of known permeability in secondary recovery of oil.[28] It was determined that a good quality water is required to flood sands of low permeability, but fair results may be obtained in flooding more permeable sands with poorer quality water.

Water of very high purity is needed for studies in certain areas of the physics and chemistry of surfaces, including those of electrochemistry and corrosion. The preparation of such water is usually carried out by heating an alkaline permanganate solution near the boiling point for many hours, followed by two or more distillations. The construction, operation, and performance of a simple still are described.[29] One or more of the stages of distillation are eliminated by replacing the usual oxidizing agent, alkaline permanganate, with oxygen. Purified oxygen is bubbled for many hours through ordinary distilled water and high-purity water is obtained routinely in a single distillation.

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[25] Donaldson. Erle C. Subsurface Disposal of Industrial Wastes in the United States. BuMines Inf. Circ. 8212, 1964, 34 pp.

[26] Robinson, T. W. Phreatophyte Research in the Western States, March 1959 to July 1964. Geol. Survey Circ. 495. 1964. 31 pp.

[27] Johansen, R. T., and R. J. Heemstra. The Effectiveness of Sodium Tripolyphosphate for Improving Injection Rates of Waterfloods. BuMines Rept. of Inv. 6557, 1964, 15 pp.

[28] Johnston. Kenneth H., and Joe L. Castagno. Evaluation by Filter Methods of the Quality of Waters Injected in Waterfloods. BuMines Rept. of Inv. 6426, 1964, 14 pp.

In selecting suitable life support systems for space missions of long duration, waste disposal, water recovery, and atmospheric control are of major concern. A moderately active man requires, on the average, at least 7 pounds of water per day including a minimum amount for washing. Several methods of water recovery from human metabolic wastes are possible, and if hydrogen-oxygen fuel cells are used for secondary (nonpropulsive) power generation, water in substantial quantities will be the byproduct. Also, for lunar expeditions, moon raw materials heated in solar or nuclear furnaces may provide additional water. The recovery of water from fuel cells and moon minerals was reviewed.[30]

Thermal pollution, the increasing burden of waste heat in streams caused by industrial waste effluent and by spent cooling water, is a growing water supply problem for government and industry.[31] It could become a major consideration in plant location, design, and operation. Thermal-pollution regulations have been enacted in several States. Besides creating algae, corrosion, and cooling problems for downstream water users, stream heating can cause (1) acceleration of chemical and biochemical reactions in river water, (2) changes in density profile within a stream, either hastening or slowing sedimentation, (3) fish kills, (4) reduced ability of a stream to degrade even normal loads of organic wastes, and (5) frequent stratification into hot and cold layers that may persist for miles downstream, again thwarting the mixing-in and degradation of wastes. Recirculating cooling towers and cooling ponds, two solutions to thermal pollution problems, can be used to insulate operations from source-water conditions and to eliminate the need to discharge spent water into natural water courses. Another type of method—the nonrecirculating tower on waste streams—is used to cool and oxygenate wastes before discharge. This controlled dispersion method discharges waste into a stretch of fast water where cooling, mixing, and aeration are handled more efficiently than in deep slow water.

Water supply for cooling is becoming critically short in many areas. By installing a cooling tower an adequate supply can usually be insured, although in some situations there may even be insufficient fresh water to make up losses by evaporation. However, a cooling tower is expensive, not only in capital costs but also in the operating cost of pumping large volumes of water to and from the tower to the exchangers. Consequently, much attention is now being given to air-cooled heat exchangers. These air-cooled exchangers are being progressively improved, but reportedly they do not have a high coefficient of heat transfer and tend to be large and expensive to install and run. The performance and operating characteristics of a reported improvement, a froth-contact heat exchanger, and the factors affecting the running costs of this exchanger compared with those of equivalent air-cooled exchangers were described.[32]

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[29] Powers, R. W. A Simplified Preparation of Very High-Purity Water. Electrochem. Tech., v. 2, No. 5–6, May–June 1964, pp. 163–166.

[30] Hendel, Frank J. Water Recovery From Fuel Cells and Lunar Minerals. Ind. and Eng. Chem., v. 56, No. 3, March 1964, pp. 29–31.

[31] Chemical Week. Heat Poses New Pollution Puzzles. V. 94, No. 6, Feb. 8, 1964, pp. 29–30.

A compendium of fundamental information on physical, chemical, and biochemical properties of water and its impurities was published.[33] Data on a wide range of topics are presented, including such diverse aspects as ionic equilibria, electrochemical causes of corrosion, the standards for water quality adopted by State health departments in the United States, and the dispersion of effluents from submerged outfalls. This book will be helpful to designers of water and waste treatment plants, to plant operators, to pollution control authorities, and to students in public health engineering.

The suspension process for reservoir evaporation control was described [34] by Russell G. Dressler, the discoverer and developer of the process. The Dressler patent discloses the utilization of fatty alcohols on reservoir surfaces in the form of aqueous suspensions or emulsions. Suspensions of 50 to 200-mesh fatty alcohol powder in water can be easily pumped and effectively solve the problem of continuous addition to reservoir surfaces at closely spaced intervals. It was found that dispensing the suspension from regularly spaced points 50 to 100 feet apart, at the rate of 0.7 to 2.0 ounces of alcohol per hour from each point, would maintain an integral film which was carried downwind. With perfect coverage the maximum water savings are about 65 percent of the unretarded evaporation loss. The calculated cost of saving water ranged from 3.5 cents per 1,000 gallons for small reservoirs to 1.4 cents for large ones. For reservoirs over 15,000 acres in size, the cost of treatment becomes less than 2.0 cents per 1,000 gallons saved.

The search for "soft" (biodegradable) detergents and the switch from the commonly used detergents based on branched-chain alkylbenzene sulfonate (ABS) to the biodegradable ones based on linear alkylate sulfonate (LAS) and linear alkylphenols (LAP) are reshaping and causing a revolution in the detergent industry. The crux of the problem is the slow rate at which ABS is broken down by bacteria to carbon dioxide, water, and simple organic substances. Efficient secondary-treatment sewage plants degrade only 40 to 60 percent of influent ABS, whereas sewage treatment will degrade more than 90 percent of influent LAS. However, under anaerobic conditions where sewage discharges into cesspools and septic tanks and under unfavorable soil conditions, biodegradability of LAS and LAP is reportedly not appreciably better than ABS. In addition, where sewage is handled by primary plants only or discharged directly to waterways, there is a question as to whether LAS biodegradability will be sufficient to eliminate foam problems. These problems, along with those of legislation, markets, materials, and processes regarding detergents are discussed in a comprehensive report.[35]

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[32] Poll, A., and W. Smith. Froth-Contact Heat Exchangers. Chem. Eng., v. 71, No. 22, Oct. 26, 1964, pp. 111–116.

[33] Camp, Thomas R. Water and Its Impurities. Reinhold Publishing Corp., New York, 1964, 355 pp.

[34] Dressler, Russell G. The Suspension Process for Reservoir Evaporation Control. Ind. and Eng. Chem., v. 56, No. 7, July 1964, pp. 36–39.

Results of Bureau of Mines investigations into the use of coals and flyashes as absorbents for removing organic contaminants from the final effluent of secondary-treated waste waters were presented in a paper at the 148th National Meeting, American Chemical Society, Division of Water and Waste Chemistry, Chicago, Ill., August 31–September 2, 1964. One coal absorbed about 4 percent of its weight of materials that consume oxygen (COD) in repetitive contacts with fresh sewage; activated carbon absorbed about 10 percent of its weight of COD at the same test conditions. A flyash removed 66 percent of the COD and 76 percent of the synthetic detergents (ABS) that were present in a single contact period. The coals, though less active than carbon, are relatively inexpensive and can still be burned as fuel after use in waste-water treatment.

A progress report was published[36] describing studies in process at the Department of Mineral Preparation in the College of Mineral Industries of The Pennsylvania State University, under sponsorship of the U.S. Department of Health, Education, and Welfare. These studies apply mineral preparation concepts or techniques of ore beneficiation to the removal of undesirable minerals and substances from sewage effluents that are stream pollutants. In the mineral froth flotation process, reagents are selected and added to an aqueous mineral slurry to react preferentially with one variety of mineral. Such a surface reaction increases the hydrophobic nature of the mineral particle. A treated particle will then respond selectively by attaching itself to an air bubble and will be displaced upward in the system by the surrounding water medium which is of greater density. The frothing reagents that are added have properties similar to those of the detergent components of sewage effluents. These properties contribute to the foaming characteristics that are intentionally sought in mineral froth flotation but which create undesirable effects in sewage effluents and streams. Using these flotation principles the system proposed for purifying the sewage effluent would be to add appropriate solids to the effluent, to inject air bubbles into the slurry, and to use the pollutants as reagents that would attach themselves to the added solid particles, and to remove the froth containing the pollutants and added solids. Preliminary results of the tests are encouraging and support the concept described.

Three separate water systems were developed for an integrated steel plant with an initial production capacity of 2.25 million tons annually. This plant is under construction at Taranto, in a part of southern Italy near the sea where there is an abundant supply of labor and good harbor facilities, but only one industrial water source of marginal quality. In one system, all facilities that could use salt water for cooling or washing were supplied with sea water, including the powerplant, blast furnaces, coke plant, and reheat furnaces. Secondly, a portion of the sea water was desalinized to provide an adequate potable and boiler feed system for the plant. Finally, for water uses in contact with the product, byproduct, or recoverable waste material, an adequate industrial water supply system was assured by chemical treatment and multiple re-use through recirculation.[37]

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[35] Winton, John. The Detergent Revolution. Chem. Week, v. 94, No. 22, May 30, 1964, pp. 111–126.

[36] Lovell, Harold L. The Application of Mineral Preparation Concepts in Water Beneficiation. Min. Industries (The Pennsylvania State University) v. 34, No. 2, November 1964, 8 pp.

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[37] Daneu, Ing. G., Ross Nebolsine, and Albert S. Toth. How Taranto Steel Plants Water Problems Were Solved. Iron and Steel Eng., v. 41, No. 9, September 1964, p. 172.

Zinc

By Harold J. Schroeder[1]

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ACTIVITY of a high level, including higher consumption, and mine and smelter production, was recorded by the zinc industry in the United States in 1964. Consumption in excess of new supplies reduced the stock level at producers to a 12-year low, leading to price increases and an emergency release of zinc from the Government stockpile.

Mine production was 574,900 tons and smelter production was 1,026,000 tons, the largest quantities since 1952 and 1957, respectively. Producers stocks dropped from 48,000 to 31,000 tons, while consumer stocks rose from 97,000 to 107,000 tons during the year.

Import quotas, established in 1958, remained in effect. General imports of ores and concentrates decreased 4 percent to 357,000 tons and of metal decreased 18 percent to 118,000 tons. Exports of slab zinc decreased 22 percent to 26,500 tons.

The quoted price of Prime Western grade zinc, East St. Louis market, advanced one-half cent in April and 1 cent in October to reach a yearend price of 14.50 cents per pound.

Government stockpiles were reduced by 75,000 tons to a yearend total of 1.5 million tons.

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[1] Commodity specialist, Division of Minerals.

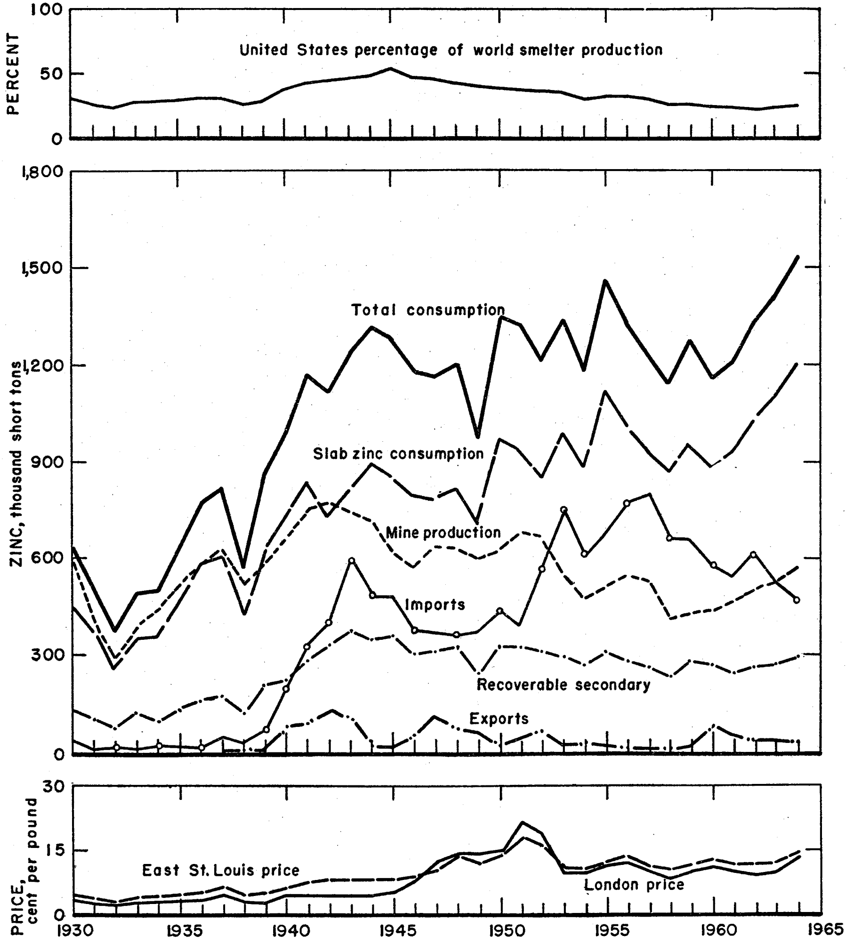

FIGURE 1.—Trends in the zinc industry in the United States.

TABLE 1.—Salient zinc statistics

	1955–59 (average)	1960	1961	1962	1963	1964
United States:						
Production:						
Domestic ores, recoverable content........short tons..	485, 211	435, 427	464, 390	505, 491	529, 254	574, 858
Value........thousands..	$116, 049	$112, 365	$106, 848	$116, 413	$122, 533	$156, 308
Slab zinc:						
From domestic ores short tons..	457, 476	334, 101	413, 282	448, 095	474, 007	531, 967
From foreign ores..do....	445, 088	465, 415	433, 513	431, 300	418, 577	422, 117
From scrap........do....	63, 015	68, 731	55, 237	58, 880	60, 303	71, 596
Total.............do....	965, 579	868, 247	902, 032	938, 275	952, 887	1, 025, 680
Secondary zinc [1]............	208, 962	197, 810	183, 357	203, 800	208, 715	227, 713
Imports (general):						
Ores (zinc content)....do....	498, 216	457, 155	415, 700	467, 398	372, 769	357, 145
Slab zinc..............do....	212, 368	120, 767	127, 562	141, 957	144, 757	118, 340
Exports of slab zinc........do....	10, 274	75, 144	50, 055	36, 102	33, 853	26, 515
Stocks, December 31:						
At producer plants....do....	120, 440	185, 882	146, 887	144, 746	47, 910	31, 178
At consumer plants....do....	103, 032	70, 361	97, 155	79, 934	r 97, 475	107, 478
Consumption:						
All classes [2]...........do....	1, 288, 840	1, 158, 938	1, 207, 469	1, 333, 311	1, 414, 216	1, 535, 751
Price, Prime Western, East St. Louis........cents per pound..	11. 79	12. 95	11. 55	11. 63	12. 01	13. 57
World:						
Production:						
Mine............short tons..	3, 405, 000	3, 680, 000	3, 805, 000	3, 925, 000	4, 020, 000	4, 395, 000
Smelter...............do....	3, 080, 000	3, 335, 000	3, 580, 000	3, 755, 000	3, 830, 000	4, 055, 000
Price: Prime Western, London cents per pound..	10. 44	11. 05	9. 78	8. 43	9. 60	14. 74

r Revised.

[1] Excludes redistilled slab zinc.

[2] Includes slab zinc, recoverable zinc content of ores and secondary zinc.

LEGISLATION AND GOVERNMENT PROGRAMS

The International Lead-Zinc Study Group held a meeting at Madrid, Spain during the last week in October. For 1964, it was estimated that free world zinc consumption would reach a record level of 3.6 million short tons. Further rises in consumption and production were forecast for 1965. The Study Group decided to expand its work to include studies on long-term trends in production and consumption and on pricing mechanisms.

Import quotas on zinc metal and ore, established October 1, 1958, were in effect throughout 1964. The annual quotas were set at 80 percent of the U.S. average annual commercial import rate from 1953 through 1957—379,840 tons of zinc in ore and 141,120 tons of zinc in pigs, slabs, and certain other forms. In response to a request by the President, the Tariff Commission began, on March 4, to investigate the condition of the lead and zinc industries with particular reference to the operation of the quota system. A report on the investigation was being prepared at yearend.

Public Law 88–374, enacted July 14, authorized release of 75,000 tons of zinc from the Government stockpile. In accordance with this authorization, General Services Administration (GSA) sold, during August 67,500 tons of zinc to domestic primary producers and 7,500 tons of zinc to "independent zinc-base alloyers" who qualified as small businesses.

GSA continued operation of the stabilization program for small domestic producers of lead and zinc. The program was authorized for 1962 through 1965 by Public Law 87–347, enacted in October 1961. The principal provisions of the law were included in the 1962 Minerals Yearbook chapter on zinc. Stabilization payments in 1964 for the 14,402 tons of zinc produced under the qualifying provisions of the Act amounted to $200,202. Zinc produced under the Act was approximately 2.5 percent of 1964 domestic mine production. From October 21 to yearend, the stabilization price equaled the market price, and hence zinc produced during this period did not qualify for payments.

Zinc was removed, effective July 1, 1962, from the list of metals eligible for exploration assistance through the Office of Minerals Exploration program. However, four contracts involving zinc awarded prior to July 1, 1962, were in force at the start of 1964. All four were terminated during the year, with one certified as a mineral discovery.

There was 1,181,000 tons of zinc in the national (strategic) stockpile and 324,000 tons in the supplementary stockpile at the end of the year. The conventional war stockpile objective for zinc, as revised in 1963 by the Office of Emergency Planning (OEP), was zero. Studies continued by OEP to determine stockpile needs to meet the requirements of general nuclear war, including reconstruction.

DOMESTIC PRODUCTION

MINE PRODUCTION

Mines in the United States produced 574,900 tons of recoverable zinc, an increase of 9 percent over that of 1963 and the highest annual output since 1952. States east of the Mississippi River produced 53 percent of the total output; Western States, 44 percent; and West Central States, 3 percent.

The sources of zinc production, classified according to types of ore, in 1964 were: 53.2 percent from zinc ores; 35.7 percent from lead-zinc ores; 0.7 percent from lead ore; 5.7 percent from copper-lead, copper-zinc, and copper-lead-zinc ores; and 4.7 percent from all other classifications. Details of this breakdown are in table 3 of the "Lead" chapter in this volume.

The 25 leading zinc-producing mines in the United States, listed in table 4, yielded 77 percent of the total domestic output. The four leading mines supplied 25 percent, and the first eight contributed 41 percent.

Tennessee maintained its rank as the leading producing State, with output increasing 21 percent to a record 115,900 tons. American Zinc, Lead and Smelting Co. operated its Coy, Mascot No. 2, Young, Grasselli, and North Friends Station mines; brought into production the New Market mine and mill, a joint venture with Tri-State Zinc Co., Inc.; and was developing a new property to be known as the Immel mine. During the first 6 months of 1964, a total of 1,090,000 tons of ore was milled to yield 51,331 tons of zinc concentrate. Exploration disclosed more ore than was mined, and reserves as of June 30 were approximately 84 million tons of ore, equivalent to about 5 million

TABLE 2.—Mine production of recoverable zinc in the United States, by States

(Short tons)

State	1955–59 (average)	1960	1961	1962	1963	1964
Arizona	29,605	35,811	29,585	32,888	25,419	24,690
Arkansas	10	50	37	211	----	----
California	3,597	465	304	322	101	143
Colorado	39,023	31,278	42,647	43,351	48,109	53,682
Idaho	53,226	36,801	58,295	62,865	63,267	59,298
Illinois	23,936	29,550	26,795	27,413	20,337	13,800
Kansas	15,514	2,117	2,446	3,943	3,508	4,665
Kentucky	637	869	1,147	1,172	1,461	2,063
Missouri	2,452	2,821	5,847	2,792	321	1,501
Montana	50,143	12,551	10,262	37,678	32,941	29,059
Nevada	3,152	420	453	281	571	582
New Jersey	5,890	----	112	15,309	32,738	32,926
New Mexico	19,327	13,770	22,900	22,015	12,938	29,833
New York	54,653	66,364	54,763	53,654	53,495	60,754
North Carolina	----	----	----	----	13	----
Oklahoma	18,065	2,332	3,148	10,013	13,245	12,159
Oregon	----	----	3	----	3	W
Pennsylvania	5,506	13,746	23,428	24,308	27,389	30,754
Tennessee	58,673	91,394	81,734	71,548	95,847	115,943
Texas	----	----	----	----	----	----
Utah	41,396	35,476	37,239	34,313	36,179	31,428
Virginia	19,882	19,885	29,163	26,479	23,988	21,004
Washington	23,011	21,317	20,217	21,644	22,270	24,296
Wisconsin	17,513	18,410	13,865	13,292	15,114	26,278
Total	485,211	435,427	464,390	505,491	529,254	574,858

W Withheld to avoid disclosing individual company confidential data.

TABLE 3.—Mine production of recoverable zinc in the United States, by months

(Short tons)

Month	1963	1964	Month	1963	1964
January	43,776	48,548	August	45,120	48,736
February	41,580	44,459	September	41,439	46,250
March	44,819	47,774	October	47,098	52,447
April	44,882	46,387	November	45,346	48,668
May	45,543	46,285	December	46,094	51,956
June	42,632	45,199			
July	40,925	48,149	Total	529,254	574,858

tons of 60 percent zinc concentrates.[2] The New Jersey Zinc Co. operated its Jefferson City mine throughout the year and early in the year resumed operations at the Flat Gap mine which had been inactive since 1961 because of low metal prices.[3] United States Steel Corp., Tennessee Coal & Iron Division, operated its Zinc Mine Works mine and mill during the year. The copper-zinc mines of Tennessee Copper Co. contributed a substantial quantity of zinc output to the State total.

New York output of recoverable zinc increased 14 percent to 60,800 tons, sufficient to make New York the second ranking zinc producer in the Nation. St. Joseph Lead Co., the only zinc producer in the State, increased the operating work week at its Balmat and Edwards mines from 40 to 48 hours on August 1. An expansion program at the Edwards mine and mill to increase daily ore capacity from 410 to 600 tons per day was scheduled for completion by July 1, 1965.[4]

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[2] American Zinc, Lead and Smelting Co. Annual Report. 1964, 24 pp.
[3] The New Jersey Zinc Co. Annual Report. 1964, p. 7.
[4] St. Joseph Lead Co. Annual Report. 1964, p. 15.

TABLE 4.—Twenty-five leading zinc-producing mines[1] in the United States in 1964 in order of output

Rank	Mine	District or region	State	Operator	Source of zinc
1	Balmat	St. Lawrence County.	New York	St. Joseph Lead Co.	Lead-zinc ore.
2	Sterling Hill	New Jersey	New Jersey	The New Jersey Zinc Co.	Zinc ore.
3	Friedensville	Lehigh County	Pennsylvania	do	Do.
4	Young	Eastern Tennessee	Tennessee	American Zinc Co. of Tennessee.	Do.
5	Eagle	Red Cliff (Battle Mountain).	Colorado	The New Jersey Zinc Co.	Do.
6	Star and Morning Unit.	Coeur d'Alene	Idaho	The Bunker Hill Co. and Hecla Mining Co.	Lead-zinc ore.
7	Austinville and Ivanhoe.	Austinville	Virginia	The New Jersey Zinc Co.	Do.
8	Butte Hill Zinc Mines (Anselmo, Badger State and others).	Summit Valley	Montana	The Anaconda Company.	Zinc ore.
9	Jefferson City	Eastern Tennessee	Tennessee	The New Jersey Zinc Co.	Do.
10	Pend Oreille	Metaline	Washington	Pend Oreille Mines and Metals Co.	Lead-zinc ore.
11	United States and Lark.	West Mountain (Bingham).	Utah	United States Smelting, Refining and Mining Co.	Do.
12	Iron King	Big Bug	Arizona	Shattuck Denn Mining Corp.	Do.
13	Zinc Mine Works	Eastern Tennessee	Tennessee	United States Steel Corp., Tennessee Coal and Iron Division.	Zinc ore.
14	Bunker Hill	Coeur d'Alene	Idaho	The Bunker Hill Co.	Lead-zinc ore.
15	Mascot No. 2	Eastern Tennessee	Tennessee	American Zinc Co. of Tennessee.	Zinc ore.
16	Flat Gap	do	do	The New Jersey Zinc Co.	Do.
17	Idarado	Upper San Miguel and Eureka (Red Mountain).	Colorado	Idarado Mining Co.	Copper-lead-zinc ore.
18	Page	Coeur d'Alene	Idaho	American Smelting and Refining Company.	Lead-zinc ore.
19	Edwards	St. Lawrence County.	New York	St. Joseph Lead Co.	Zinc ore.
20	Copperhill	Eastern Tennessee	Tennessee	Tennessee Copper Co.	Copper-zinc ore.
21	Kearney	Central	New Mexico	American Zinc, Lead and Smelting Company.	Zinc ore.
22	Shullsburg	Upper Mississippi Valley.	Wisconsin	The Eagle-Picher Co.	Do.
23	New Market	Eastern Tennessee	Tennessee	New Market Zinc Company.	Do.
24	Hanover	Central	New Mexico	The New Jersey Zinc Co.	Do.
25	Oswaldo	do	do	The New Jersey Zinc Co.	Do.

[1] Excludes old slag dumps.

Idaho remained the leading zinc producer in the Western States, although output declined 6 percent to 59,300 tons. The Bunker Hill Co. reported 24,955 tons of zinc in concentrate recovered from milling 245,400 tons of ore from its Star Unit mines and 16,817 tons of zinc in concentrate from milling 454,300 tons of ore from its Bunker Hill mine.[5] The Page mine of American Smelting and Refining Company was also a substantial producer of zinc.

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[5] The Bunker Hill Co. Annual Report. 1964, p. 12.

In Colorado, zinc production increased 12 percent to 53,700 tons. Leading zinc producing mines were the Eagle of The New Jersey Zinc Co., the Idarado of Idarado Mining Co., the Emperius of Emperius Mining Co., the Sunnyside of Standard Metals Corp., and the Keystone mine operated by McFarland and Hullinger.

Zinc production in New Jersey was 32,900 tons, slightly higher than in 1963 despite a strike closing the Sterling mine of The New Jersey Zinc Co. for 33 days during August and September.

In Utah, zinc production decreased 13 percent to 31,400 tons, the lowest level since 1953. The United States and Lark mine of United States Smelting, Refining and Mining Co. was the leading zinc producer in the State. Other substantial producers were the United Park City mines of United Park City Mines Co., Mayflower mine of Hecla Mining Co., and the Ophir mine of United States Smelting, Refining and Mining Co. According to its annual report, the United Park City Mines Co. mined 65,000 tons of ore yielding 7,837 tons of zinc plus quantities of lead, copper, silver, and gold.

Pennsylvania output of zinc increased 12 percent to 30,800 tons, the largest quantity since zinc production was resumed in 1958. The only operating mine was the Friedensville of The New Jersey Zinc Co.

Production in New Mexico more than doubled to 29,800 tons, the highest output since 1957. The largest producing mines were the Kearney of American Zinc, Lead and Smelting Co. and the Hanover and Oswaldo mines of The New Jersey Zinc Co. In May, the United States Smelting, Refining and Mining Co. reopened the Princess mine.

In Montana, production decreased 3,900 tons to 29,100 tons. Most of the output was by The Anaconda Company from mines near Butte and from a slag-fuming operation at East Helena. The largest producing mine was the Badger State, which employed both block-caving and cut-and-fill methods. Zinc production also came from the Anselmo mine, Syndicate pit and dump, Orphan Girl dump, Emma West dump, and from processing ore from the Government low-grade manganese stockpile purchased in 1962.

Zinc output in Wisconsin increased by 74 percent to 26,300 tons, the highest production since 1927. The Eagle-Picher Co., American Zinc, Lead and Smelting Co., and Grimes Mining Co. operated mines and mills throughout the year. Mines were reopened during the year by Mifflin Mining Co. and Piquette Mining and Milling Co. Ivey Construction Co. discontinued operations at its Linden mine in September.

Arizona mine output declined for the second year to 24,700 tons, the lowest level since 1955. The Iron King mine of Shattuck Denn Mining Corp. continued to be the largest zinc producer in the State. Other zinc-producing properties in the State included the Atlas mine of B. S. & K. Mining Co. and the Old Dick and Copper Queen mines of Cyprus Mines Corp.

In Washington, zinc mine output increased 9 percent to 24,300 tons, the highest level since 1956. The Pend Oreille mine, Pend Oreille Mines and Metals Co., yielded 15,797 tons of zinc in concentrate and

4,763 tons of lead in concentrate from 619,900 tons of ore mined and milled.[6] American Zinc, Lead and Smelting Co. operated the Grandview and Mineral Rights mines until September 10 when they were closed due to depletion of reserves. The company plans to transfer milling and mining facilities to the Anderson Ranch Property in Stevens County for development of a new mine to be called the Calhoun. Initial production is scheduled for December 1965 at a rate of about 1,000 tons of ore per day.[7] American Smelting and Refining Company brought its Van Stone mine into production in July.

Virginia zinc mine production decreased for the third year to 21,000 tons. The New Jersey Zinc Co. operated the Austinville and Ivanhoe mines throughout the year.

In the Tri-State District of Oklahoma, Kansas, and Missouri, production remained at 16,800 tons. The Oklahoma portion of the district accounted for 72 percent of the production, and Kansas produced the remainder. The southwest Missouri portion of the district last reported production in 1957.

Zinc output from Illinois declined to a 16-year low of 13,800 tons. The Graham mine of The Eagle-Picher Co. was the only producer of zinc in northern Illinois. Output of zinc as a byproduct of fluorspar mines in southern Illinois was curtailed due to a lower fluorspar demand.

Kentucky produced 2,100 tons of zinc as a byproduct from fluorspar mining operations and from the Hutson zinc mine reopened in September by The Eagle-Picher Co.

Mine production of zinc from Missouri, all as a byproduct from lead mining in southeast Missouri, was 1,500 tons.

SMELTER AND REFINERY PRODUCTION

The zinc smelting and refining industry operated 13 primary and 8 secondary reduction plants producing slab zinc. The zinc reduction plant of Athletic Mining & Smelting Co. at Fort Smith, Ark., terminated production late in 1963 and was sold to the Arkansas-Louisiana Gas Co., Fort Smith Gas Corp., and Stevens Production Co. The plant was idle during 1964 and no plans were announced regarding future operations. Producers of slab zinc also made zinc compounds, alloys, zinc dust, and rolled zinc.

Domestic smelters had no significant interruption to operation by labor strikes during the year. Production at a number of smelters was curtailed due to a shortage of available concentrates relative to the demand for slab zinc.

Changes in zinc producing facilities listed in company annual reports were as follows: American Zinc, Lead and Smelting Co. increased the capacity of its Monsanto electrolytic plant by 15 percent late in 1964, The New Jersey Zinc Co. installed new auxiliary equipment to complete the 1963 addition to slab zinc producing facilities at its Depue, Ill., plant, and St. Joseph Lead Co. completed construction at its Josephtown plant to increase capacity for production of Special High Grade zinc from 2,200 to 3,700 tons per month.

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[6] Pend Oreille Mines and Metals Co. Annual Report. 1964, p. 3.

[7] American Zinc, Lead and Smelting Co. Annual Report. 1964, p. 10.

Slab Zinc.—Domestic smelter output of slab zinc increased for the sixth consecutive year and was the highest for any year since 1957. Included in the 1,026,000 tons of slab zinc output was molten zinc, used directly in alloying operations. Of the total, 954,100 tons was primary metal and 71,600 tons was redistilled secondary zinc. Primary output was 56 percent from domestic ores and 44 percent from foreign ores; 41 percent was electrolytic and 59 percent was distilled slab zinc. Of the 71,600 tons of redistilled secondary slab zinc, primary smelters produced 80 percent, and the remainder was obtained from secondary smelters.

In 1964, Special High Grade was the principal grade produced, furnishing 46 percent of the total. Prime Western Grade constituted

TABLE 5.—Primary and redistilled secondary slab zinc produced in the United States

(Short tons)

	1955–59 (average)	1960	1961	1962	1963	1964
Primary:						
From domestic ores	457,476	334,101	413,282	448,095	474,007	531,967
From foreign ores	445,088	465,415	433,513	431,300	418,577	422,117
Total	902,564	799,516	846,795	879,395	892,584	954,084
Redistilled secondary	63,015	68,731	55,237	58,880	60,303	71,596
Total (excludes zinc recovered by remelting)	965,579	868,247	902,032	938,275	952,887	1,025,680

TABLE 6.—Distilled and electrolytic zinc, primary and secondary, produced in the United States, by method of reduction

(Short tons)

Method of reduction	1955–59 (average)	1960	1961	1962	1963	1964
Electrolytic primary	363,411	319,777	324,399	354,138	358,093	389,383
Distilled	539,154	479,739	522,396	525,257	534,491	564,701
Redistilled secondary:						
At primary smelters	28,586	40,009	35,319	41,732	47,214	57,546
At secondary smelters	34,428	28,722	19,918	17,148	13,089	14,050
Total	965,579	868,247	902,032	938,275	952,887	1,025,680

TABLE 7.—Distilled and electrolytic zinc, primary and secondary, produced in the United States, by grades

(Short tons)

Grade	1955–59 (average)	1960	1961	1962	1963	1964
Special High Grade	343,753	357,205	353,466	392,901	411,254	468,748
High Grade	122,406	71,332	89,496	94,185	104,301	112,056
Intermediate	26,125	15,841	15,368	14,101	18,372	19,050
Brass Special	83,588	83,507	69,681	75,951	98,190	81,034
Select	2,034	73	----------	130	3,909	326
Prime Western	387,673	340,289	374,021	361,007	316,861	344,466
Total	965,579	868,247	902,032	938,275	952,887	1,025,680

33 percent; High Grade, 11 percent; Brass Special, 8 percent; and Intermediate and Select, 2 percent.

Pennsylvania was the leading producing State, with Texas ranking second and Oklahoma third. The slab zinc output of Pennsylvania, West Virginia, and Oklahoma was produced by the distillation process; the output of Montana and Idaho, by the electrolytic process. Part of the Illinois and Texas slab output was distilled and part was electrolytic.

Primary Smelters and Electrolytic Plants.—Primary reduction plants processed roasted zinc ores and concentrates, zinc fume from Waelz kilns and slag-fuming plants, other primary zinc-bearing materials, and zinc-base scrap.

Production at primary zinc plants totaled 1,011,600 tons of slab zinc of which 57,500 tons was from scrap. In addition to slab zinc, primary plants produced zinc oxide, zinc dust, and zinc-base alloys.

TABLE 8.—Primary slab zinc produced in the United States, by States where smelted

(Short tons)

State	1955–59 (average)	1960	1961	1962	1963	1964
Arkansas	21, 226	1, 521	12, 342	14, 446	11, 143	
Idaho	59, 980	26, 449	74, 736	76, 756	81, 296	91, 761
Illinois [1]	100, 436	88, 291	78, 814	99, 055	108, 971	114, 866
Montana	171, 140	132, 290	111, 223	129, 144	118, 090	125, 334
Oklahoma	151, 795	161, 894	164, 319	147, 384	142, 707	150, 356
Pennsylvania and West Virginia	227, 443	194, 514	214, 308	234, 038	248, 584	262, 981
Texas	170, 544	194, 557	191, 053	178, 572	181, 793	208, 786
Total	902, 564	799, 516	846, 795	879, 395	892, 584	954, 084
Value (thousand)	$215, 865	$205, 476	$193, 916	$201, 733	$206, 187	$260, 274

[1] Includes production for Missouri for 1955, 1956, 1957, and 1960.

TABLE 9.—U.S. primary zinc plants, their location and group capacity for slab zinc in 1964

Type of plant	Plant location	Slab zinc capacity (short tons)
Electrolytic plants:		
American Smelting and Refining Company	Corpus Christi, Tex	512, 200
American Zinc Co. of Illinois	Monsanto, Ill	
The Anaconda Company [1]	Anaconda, Mont	
Do	Great Falls, Mont	
The Bunker Hill Co	Kellogg, Idaho	
Horizontal-retort plants:		
American Smelting and Refining Company	Amarillo, Tex	700, 800
American Zinc Co. of Illinois	Dumas, Tex	
Athletic Mining & Smelting Co.[1]	Fort Smith, Ark	
Blackwell Zinc Co., Division of American Metal Climax, Inc.	Blackwell, Okla	
The Eagle-Picher Co	Henryetta, Okla	
Matthiessen & Hegeler Zinc Co.[2]	LaSalle, Ill	
National Zinc Co	Bartlesville, Okla	
Vertical-retort plants:		
Matthiessen & Hegeler Zinc Co	Meadowbrook, W. Va	
The New Jersey Zinc Co	Depue, Ill	
Do	Palmerton, Pa	
St. Joseph Lead Co.[3]	Herculaneum, Mo	
Do	Josephtown, Pa	

[1] Plant not operated in 1964.

[2] Plant closed July 1, 1961.

[3] Electrothermic slag-fuming unit, yielding a slab zinc product.

Capacity for slab zinc production at the primary zinc plants at yearend was reported to be 1,213,000 tons. Electrolytic plants reported 2,745 of their 4,232 electrolytic cells in use at the end of the year and an output of 389,400 tons (76 percent of the 512,200 tons of capacity). The horizontal-retort plants reported 33,344 of the 39,468 retorts in use during 1964. The remaining primary smelters were continuous-distilling vertical-retort plants. Combined horizontal- and vertical-retort production of 622,200 tons was 89 percent of the reported 1964 capacity of 700,800 tons.

Slag-Fuming Plants.—Many lead smelters recover a zinc-fume product from lead blast-furnace slags containing about 7 to 13 percent zinc. Such slags were treated to extract zinc and remaining lead by the following companies in 1964:

Company:	*Plant Location*
American Smelting and Refining Company	Selby, Calif.
Do	El Paso, Tex.
The Anaconda Company	East Helena, Mont.
The Bunker Hill Co	Kellogg, Idaho.
International Smelting & Refining Co	Tooele, Utah.

These five plants treated 731,200 tons of hot and cold lead slag (including some crude ore and zinc residue), which yielded 130,500 tons of oxide fume, containing 93,400 tons of recoverable zinc. Corresponding figures for 1963 were 705,300 tons of slag, 122,300 tons of fume, and 87,000 tons of recoverable zinc.

Secondary Zinc Smelters.—Zinc-base scrap (including skimmings and drosses, die-cast alloys, old zinc, engravers' plates, new clippings, and chemical residues) was smelted chiefly at secondary smelters, although about one-third was reduced at primary smelters and most sal ammoniac skimmings were processed at chemical plants.

Primary and secondary smelting plants produced from zinc-base scrap 71,600 tons of redistilled zinc, 5,300 tons of remelted products, and 29,700 tons of zinc dust. The zinc content of these products totaled 105,200 tons.

TABLE 10.—U.S. secondary zinc plants, their location and capacity for slab zinc in 1964

Company	Plant location	Slab zinc capacity (short tons)
American Smelting and Refining Company [1]	Beckemeyer, Ill	53,500
Do	Sand Springs, Okla	
Do	Trenton, N.J	
American Zinc Co. of Illinois	Hillsboro, Ill	
Apex Smelting Co	Chicago, Ill	
Arco Die Cast Metals Co	Detroit, Mich	
W. J. Bullock, Inc	Fairfield, Ala	
General Smelting Co	Bristol, Pa	
Gulf Reduction Co	Houston, Tex	
H. Kramer Co	El Segundo, Calif	
Pacific Smelting Co	Torrance, Calif	
Sandoval Zinc Co	Sandoval, Ill	
Superior Zinc Corp	Bristol, Pa	
Wheeling Steel Corp	Martins Ferry, Ohio	

[1] Plant closed May 1964.

TABLE 11.—Stocks and consumption of new and old zinc scrap in the United States in 1964

(Short tons)

Class of consumer and type of scrap	Stocks Jan. 1[1]	Receipts	Consumption			Stocks Dec. 31
			New scrap	Old scrap	Total	
Smelters and distillers:						
New clippings	155	1,121	1,199	----------	1,199	77
Old zinc	551	4,663	----------	4,744	4,744	470
Engravers' plates	391	2,690	----------	2,900	2,900	181
Skimmings and ashes	10,749	55,830	59,241	----------	59,241	7,338
Sal skimmings	189	331	272	----------	272	248
Die-cast skimmings	1,465	3,720	4,255	----------	4,255	930
Galvanizers' dross	7,784	63,194	63,308	----------	63,308	7,670
Diecastings	3,407	29,936	----------	31,406	31,406	1,937
Rod and die scrap	735	1,908	----------	1,613	1,613	1,030
Flue dust	991	8,547	7,827	----------	7,827	1,711
Chemical residues	811	10,408	10,298	----------	10,298	921
Total	27,228	182,348	146,400	40,663	187,063	22,513
Chemical plants, foundries and other manufacturers:						
New clippings	----------	6	6	----------	6	----------
Old zinc	3	20	----------	15	15	8
Engravers' plates	----------	49	----------	49	49	----------
Skimmings and ashes	2,549	7,550	8,806	----------	8,806	1,293
Sal skimmings	7,164	9,462	9,865	----------	9,865	6,761
Die-cast skimmings	----------	----------	----------	----------	----------	----------
Galvanizers' dross	----------	----------	----------	----------	----------	----------
Diecastings	19	515	----------	507	507	27
Rod and die scrap	17	52	----------	55	55	14
Flue dust	86	8	71	----------	71	23
Chemical residues	1,074	19,762	20,017	----------	20,017	819
Total	10,912	37,424	38,765	626	39,391	8,945
Grand total:						
New clippings	155	1,127	1,205	----------	1,205	77
Old zinc	554	4,683	----------	4,759	4,759	478
Engravers' plates	391	2,739	----------	2,949	2,949	181
Skimmings and ashes	13,298	63,380	68,047	----------	68,047	8,631
Sal skimmings	7,353	9,793	10,137	----------	10,137	7,009
Die-cast skimmings	1,465	3,720	4,255	----------	4,255	930
Galvanizers' dross	7,784	63,194	63,308	----------	63,308	7,670
Diecastings	3,426	30,451	----------	31,913	31,913	1,964
Rod and die scrap	752	1,960	----------	1,668	1,668	1,044
Flue dust	1,077	8,555	7,898	----------	7,898	1,734
Chemical residues	1,885	30,170	30,315	----------	30,315	1,740
Total	38,140	219,772	185,165	41,289	226,454	31,458

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[1] Figures partly revised.

TABLE 12.—Production of secondary zinc and zinc-alloy products in the United States

(Short tons)

Product	1955–59 (average)	1960	1961	1962	1963	1964
Redistilled slab zinc	63,015	[1] 68,731	[1] 55,237	[1] 58,880	60,303	71,596
Zinc dust	24,842	26,681	22,878	24,863	23,749	29,742
Remelt spelter	5,855	4,883	4,260	3,540	3,740	3,646
Remelt die-cast slab	12,417	7,800	9,548	10,834	10,168	8,934
Zinc-die and diecasting alloys	5,814	6,945	5,894	5,531	5,894	5,116
Galvanizing stocks	286	222	117	369	611	1,684
Rolled zinc	1,061	18	19	14	4	----------
Secondary zinc in chemical products	33,128	38,007	35,639	36,331	35,210	36,130

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[1] Includes redistilled slab made from remelt die-cast slab.

TABLE 13.—Zinc recovered from scrap processed in the United States, by kind of scrap and form of recovery

(Short tons)

Kind of scrap	1963	1964
New scrap:		
Zinc-base	110,886	124,342
Copper-base	91,592	102,913
Aluminum-base	3,144	2,866
Magnesium-base	69	209
Total	205,691	230,330
Old scrap:		
Zinc-base	32,572	33,375
Copper-base	27,634	31,716
Aluminum-base	2,302	2,832
Magnesium-base	56	141
Total	62,564	68,064
Grand total	268,255	298,394

Form of recovery	1963	1964
As metal:		
By distillation:		
Slab zinc [1]	59,540	70,681
Zinc dust	23,417	29,296
By remelting	4,317	5,178
Total	87,274	105,155
In zinc-base alloys	14,940	13,073
In brass and bronze	125,087	137,619
In aluminum-base alloys	5,543	5,997
In magnesium-base alloys	201	420
In chemical products:		
Zinc oxide (lead-free)	18,591	18,722
Zinc sulfate	(2)	6,206
Zinc chloride	10,768	10,968
Miscellaneous	5,851	234
Total	180,981	193,239
Grand total	268,255	298,394

[1] Includes zinc content of redistilled slab made from remelt die-cast slab.

(2) Included with "Miscellaneous."

TABLE 14.—Zinc dust produced in the United States

Year	Short tons	Value	
		Total	Average per pound
1955–59 (average)	28,830	$8,676,134	$0.150
1960	30,788	10,283,192	.167
1961	34,772	10,570,688	.152
1962	40,978	$12,539,268	$0.153
1963	40,362	12,592,944	.156
1964	45,979	15,724,818	.171

Details on the zinc recovered in processing copper-base scrap may be obtained in the secondary copper and brass section of the "Copper" chapter of this volume.

BYPRODUCT SULFURIC ACID

Sulfuric acid was made from sulfur dioxide gases produced in roasting zinc sulfide concentrate at primary zinc plants. At several plants, elemental surfur was burned to increase acid-making capacity. Acid production at zinc-roasting plants from zinc sulfide was 924,100 short tons, valued at $12.2 million, and from elemental sulfur, 131,200 tons, valued at $1.7 million.

ZINC DUST

Zinc dust data included in the tables are restricted to commercial grades that comply with close specifications as to percentage of unoxidized metal, evenness of grading, and fineness of particles; they do not include blue powder. Zinc content of the dust produced ranged from 95.42 to 99.98 percent, averaging 98.50 percent. Production of zinc dust increased 14 percent to a record 46,000 tons.

CONSUMPTION AND USES

Both slab and total zinc consumed were at record levels. In the consumption of slab zinc nearly all product categories increased with a record attained for zinc-base alloys for the second consecutive year.

Of the 1.2 million tons of slab zinc used, 50 percent was Special High Grade, 29 percent Prime Western, 9 percent High Grade, 10 percent Brass Special, 1 percent Intermediate, and 1 percent Select and Remelt combined. All grades were used in galvanizing and in brass and

TABLE 15.—Consumption of zinc in the United States

(Short tons)

	1955–59 (average)	1960	1961	1962	1963	1964
Slab zinc	977,749	877,884	931,213	1,031,821	1,105,113	1,207,268
Ores (recoverable zinc content)	108,961	[1] 88,275	[1] 97,251	[1] 101,582	[1] 104,705	105,948
Secondary (recoverable zinc content)[2]	202,130	192,779	179,005	199,908	204,398	222,535
Total	1,288,840	1,158,938	1,207,469	1,333,311	1,414,216	1,535,751

[1] Includes ore used directly in galvanizing.

[2] Excludes redistilled slab and remelt zinc.

TABLE 16.—Reported slab zinc consumption in the United States, by industry use

(Short tons)

Industry and product	1955–59 (average)	1960	1961	1962	1963	1964
Galvanizing:						
Sheet and strip	188,445	196,057	211,300	213,970	238,919	257,328
Wire and wire rope	39,763	35,262	37,608	38,203	39,466	42,793
Tubes and pipe	76,419	56,680	54,957	54,003	56,563	62,166
Fittings	10,069	9,258	6,540	8,039	7,787	8,802
Other	85,364	[1] 74,332	[1] 71,672	[1] 74,355	[1] 77,552	[1] 85,247
Total	400,060	371,589	382,077	388,570	420,287	456,336
Brass products:						
Sheet, strip, and plate	56,966	45,870	60,018	61,210	61,462	64,701
Rod and wire	38,562	29,971	41,018	41,875	43,517	47,246
Tube	12,479	8,504	10,168	10,627	10,786	10,402
Castings and billets	5,813	4,699	4,061	4,923	3,969	3,258
Copper-base ingots	7,983	9,412	12,874	10,884	7,784	8,565
Other copper-base products	855	567	384	286	719	923
Total	122,658	99,023	128,523	129,805	128,237	135,095
Zinc-base alloy:						
Die casting alloy	364,626	331,112	337,227	419,042	462,543	517,354
Dies and rod alloy	8,074	3,442	1,629	850	720	604
Slush and sand casting alloy	2,003	3,819	2,910	3,716	5,356	6,624
Total	374,703	338,373	341,766	423,608	468,619	524,582
Rolled zinc	44,756	38,696	41,204	42,233	42,166	44,181
Zinc oxide	18,720	15,593	18,137	18,517	16,037	19,991
Other uses:						
Wet batteries	1,238	1,152	1,058	1,133	1,216	1,168
Desilverizing lead	2,579	2,521	2,630	2,302	2,095	2,393
Light-metal alloys	4,258	3,181	4,347	4,920	5,660	4,769
Other[2]	8,777	7,756	11,471	20,733	20,796	18,753
Total	16,852	14,610	19,506	29,088	29,767	27,083
Grand total	977,749	877,884	931,213	1,031,821	1,105,113	1,207,268

[1] Includes 31,616 tons used in job galvanizing in 1960, 30,954 tons in 1961, 34,871 tons in 1962, 39,223 tons in 1963, and 44,354 tons in 1964.

[2] Includes zinc used in making zinc dust, bronze powder, alloys, chemicals, castings, and miscellaneous uses not elsewhere mentioned.

bronze products. Of the 525,000 tons of slab zinc used in zinc-base alloys, 99 percent was Special High Grade.

Rolling mills used 44,000 tons of slab zinc and remelted and rerolled 14,600 tons of metallic scrap produced in fabricating plants operated in connection with the rolling mills. In addition, a small quantity of purchased scrap (new clippings and old zinc) was melted and rolled. Small quantities of alloying metals were added for some uses. The rolled-zinc industry, however, classified these alloys as rolled zinc.

Output of salable rolled zinc increased to 43,000 tons. Stocks of rolled zinc at the mills declined to 1,800 tons by yearend. Besides shipments of 22,100 tons of rolled zinc, the rolling mills consumed 36,100 tons of rolled zinc in manufacturing 22,600 tons of semifabricated and finished products.

Rolled zinc was produced in the forms of sheet, strip, ribbon, plate, rod, and wire. Its major domestic use was for dry cell battery cases and similar cases for radio condensers and tube shields. Weatherstripping, roof flashing, photoengraving plates, and household electric fuses were other uses.

TABLE 17.—Reported slab zinc consumption in the United States in 1964, by grades and industry use

(Short tons)

Industry	Special High Grade	High Grade	Intermediate	Brass Special	Select	Prime Western	Remelt	Total
Galvanizing	29,551	24,467	1,666	97,637	483	299,727	2,805	456,336
Brass and bronze	25,695	75,033	354	4,098	2,407	24,791	2,717	135,095
Zinc-base alloys	518,101	3,693	135	---	155	1,068	1,430	524,582
Rolled zinc	21,061	10,125	4,943	8,027	---	25	---	44,181
Zinc oxide	5,258	3	---	---	---	14,730	---	19,991
Other	9,609	1,424	338	9,372	---	5,855	485	27,083
Total	609,275	114,745	7,436	119,134	3,045	346,196	7,437	1,207,268

TABLE 18.—Rolled zinc produced and quantity available for consumpton in the United States

	1963			1964		
	Short tons	Value		Short tons	Value	
		Total	Average per pound		Total	Average per pound
Production:						
Sheet zinc not over 0.1 inch thick	13,787	$7,743,180	$0.281	15,538	$7,929,548	$0.255
Boiler plate and sheets over 0.1 inch thick	159	64,238	.202	W	W	W
Strip and ribbon zinc [1]	25,117	9,806,651	.195	25,580	11,269,831	.220
Foil, rod, and wire	1,955	1,058,159	.271	W	W	W
Total rolled zinc	41,018	18,672,228	.228	42,964	20,201,411	.235
Imports	1,532	413,331	.135	1,774	526,990	.149
Exports	3,756	2,741,874	.365	6,569	3,978,434	.303
Available for consumption	39,032	---	---	38,819	---	---
Value of slab zinc (all grades)	---	---	.115	---	---	.136
Value added by rolling	---	---	.113	---	---	.099

W Withheld to avoid disclosing individual company confidential data.

[1] Figures represent net production. In addition, 12,137 tons of strip, ribbon, and sheet zinc in 1963 and 14,550 tons in 1964 were rerolled from scrap originating in fabricating plants operating in connection with zinc rolling mills.

CONSUMPTION OF SLAB ZINC, BY GEOGRAPHIC AREAS

Ohio, Pennsylvania, Indiana, and Illinois accounted for 59 percent of the slab zinc used in galvanizing. The iron and steel industry used zinc to galvanize steel sheets, wire, tube, pipe, cable, chain, bolts, railway-signal equipment, building and pole-line hardware, and other items.

Connecticut again ranked first in consuming slab zinc in brass making, followed by Illinois and Michigan.

Michigan led in the consumption of slab zinc in making zinc-base alloys. Other large consuming States were Illinois, Ohio, New York, and Indiana.

TABLE 19.—Reported slab zinc consumption in the United States in 1964, by industries and States

(Short tons)

State	Galvanizers	Brass mills [1]	Die casters [2]	Other [3]	Total
Alabama	35,245	W	---	W	36,328
Arizona	W	---	---	W	W
Arkansas	---	---	---	W	W
California	28,635	1,715	10,968	697	42,015
Colorado	W	W	W	---	W
Connecticut	3,349	43,486	W	W	49,709
Delaware	W	W	W	W	W
Florida	W	---	W	---	2,912
Georgia	W	---	---	---	W
Hawaii	W	---	---	---	W
Idaho	---	---	W	W	W
Illinois	45,913	18,199	75,453	21,403	160,968
Indiana	60,039	W	38,683	W	122,475
Iowa	W	---	---	W	1,846
Kansas	---	---	W	---	W
Kentucky	W	W	---	---	W
Louisiana	W	---	---	W	1,596
Maine	W	---	---	---	W
Maryland	W	W	---	W	33,719
Massachusetts	3,809	2,326	---	W	8,198
Michigan	W	14,668	133,172	W	154,071
Minnesota	2,301	---	---	---	2,301
Mississippi	W	---	---	---	W
Missouri	5,379	W	8,206	W	14,803
Nebraska	W	W	---	W	1,889
New Hampshire	---	W	---	---	W
New Jersey	3,625	6,056	W	W	28,977
New York	5,585	W	55,483	W	78,608
North Carolina	W	---	W	---	W
Ohio	91,971	W	75,109	W	176,678
Oklahoma	2,915	---	W	W	5,727
Oregon	W	W	---	W	537
Pennsylvania	70,664	W	23,640	W	134,056
Rhode Island	W	W	---	W	702
South Carolina	W	---	---	---	W
Tennessee	W	---	W	W	2,138
Texas	14,423	W	W	W	47,340
Utah	W	W	---	---	W
Virginia	180	W	W	W	1,120
Washington	W	---	---	W	1,444
West Virginia	11,507	W	---	W	12,176
Wisconsin	2,064	W	7,215	W	16,745
Undistributed	65,927	45,928	95,223	68,670	60,753
Total [4]	453,531	132,378	523,152	90,770	1,199,831

W Withheld to avoid disclosing individual company confidential data; included with "Undistributed."

[1] Includes brass mills, brass ingot makers, and brass foundries.

[2] Includes producers of zinc-base alloy for diecastings, stamping dies, and rods.

[3] Includes slab zinc used in rolled zinc products and in zinc oxide.

[4] Excludes remelt zinc.

ZINC PIGMENTS AND COMPOUNDS

Production.—Output of zinc pigments and compounds, excluding lithopone, increased to the highest level since 1959. Most of the increase was accounted for by the highest output of lead-free zinc oxide since 1955 and a record production of zinc sulfate. Zinc chloride also rose 3 percent, while leaded zinc oxide declined, continuing the downward trend during the past 17 years.

TABLE 20.—Production and shipments of zinc pigments and compounds[1] in the United States

Pigment or compound	1963				1964			
	Production (short tons)	Shipments			Production (short tons)	Shipments		
		Short tons	Value[2]			Short tons	Value[2]	
			Total	Average per ton			Total	Average per ton
Zinc oxide[3]	157,371	162,271	$37,747,259	$233	163,305	174,303	$41,970,758	$241
Leaded zinc oxide[3]	15,060	15,473	3,508,621	227	12,237	13,613	3,246,038	238
Zinc chloride, 50° B[4]	49,728	50,922	W	W	50,977	49,624	W	W
Zinc sulfate	40,109	40,111	5,450,019	136	46,314	46,606	7,021,601	151

W Withheld to avoid disclosing individual company confidential data.

[1] Excludes lithopone; figure withheld to avoid disclosing individual company confidential data.

[2] Value at plant, exclusive of container.

[3] Zinc oxide containing 5 percent or more lead is classed as leaded zinc oxide.

[4] Includes zinc chloride equivalent of zinc ammonium chloride and chromated zinc chloride.

Pigments and compounds were made from various zinc-bearing materials, including ore, slab zinc, scrap, and residues. Plants producing zinc pigments and compounds numbered 16 for zinc oxide, 10 for zinc sulfate, 8 for zinc chloride, and 1 for lithopone.

TABLE 21.—Zinc content of zinc pigments[1] and compounds produced by domestic manufacturers, by sources

(Short tons)

Pigment or compound	1963					1964				
	Zinc in pigments and compounds produced from—				Total zinc in pigments and compounds	Zinc in pigments and compounds produced from—				Total zinc in pigments and compounds
	Ore		Slab zinc	Secondary material		Ore		Slab zinc	Secondary material	
	Domestic	Foreign				Domestic	Foreign			
Zinc oxide	65,245	16,250	16,037	28,026	125,558	70,728	13,487	19,991	26,136	130,342
Leaded zinc oxide	5,165	4,087	-------	-------	9,252	4,714	2,780	-------	-------	7,494
Total pigments	70,410	20,337	16,037	28,026	134,810	75,442	16,267	19,991	26,136	137,836
Zinc chloride[2]	-------	-------	W	11,130	11,130	-------	-------	W	W	12,315
Zinc sulfate	W	W	-------	W	13,372	W	W	-------	6,206	14,921

W Figure withheld to avoid disclosing individual company confidential data.

[1] Excludes zinc sulfide and lithopone; figures withheld to avoid disclosing individual company confidential data.

[2] Includes zinc content of zinc ammonium chloride and chromated zinc chloride.

Lead-free zinc oxide was made by several processes; 66 percent was made from ores and residues by the American process, 19 percent from metal made by the French process, and 15 percent from scrap residues and secondary materials by other processes. Leaded zinc oxide was made from ores, zinc chloride was made from slab zinc and secondary zinc materials, and zinc sulfate was made from ores and secondary materials.

Four grades of leaded zinc oxide, classified according to lead content, were produced. The more than 5 to 35 percent grade constituted most of the production. Relatively small quantities of the 5 percent or less, the more than 35 to 50 percent, and over 50 percent grades were produced.

Lithopone, a coprecipitate of zinc sulfide and barium sulfate, was produced, but figures are withheld to avoid disclosing individual company confidential data.

Consumption and Uses.—Shipments of lead-free zinc oxide were 174,300 tons, 7 percent greater than in 1963. The quantity received by the rubber, paint, and ceramic industries accounted for 77 percent of the total shipped.

The paint industry received 96 percent of the 13,600 tons of leaded zinc oxide shipped.

Lithopone was used in paint, varnish and lacquer, coated fabrics and textiles, rubber, and floor covering.

The principal uses of zinc chloride were for battery making, galvanizing, vulcanizing fiber, preserving wood, and refining oil, as well as for fungicides, solder and timing fluxes.

The chief uses of zinc sulfate were in rayon and agriculture. Other uses were in glue manufacture, flotation reagents, rubber, and medicine.

Prices.—Prices for lead-free zinc oxides advanced 0.50 cent in May and 0.75 cent in October. Yearend quotations in cents per pound in carlots, freight allowed, was 14.75 cents for American-process zinc oxide, and quotations for Green-seal and White-seal French-process zinc

TABLE 22.—Distribution of zinc oxide and leaded zinc oxide shipments, by industries

(Short tons)

Industry	1955–59 (average)	1960	1961	1962	1963	1964
Zinc oxide:						
Rubber	79,313	75,120	71,534	80,247	82,776	93,568
Paints	33,213	31,610	30,405	31,381	34,382	31,176
Ceramics	9,763	9,840	10,058	11,092	9,381	9,447
Coated fabrics and textiles [1]	5,557	1,331	1,185	202	(2)	(2)
Floor coverings	1,429	1,316	1,174	457	(2)	438
Other	23,723	25,561	30,852	31,470	35,732	39,674
Total	152,998	144,778	145,208	154,849	162,271	174,303
Leaded zinc oxide:						
Paints	25,335	17,616	16,533	14,959	14,899	13,124
Rubber	653	1,662	1,474	735	574	489
Other						
Total	25,988	19,278	18,007	15,694	15,473	13,613

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[1] Figures for zinc oxide used for rayon are withheld to avoid disclosing individual company confidential data.

[2] Included with "Other."

oxide were 16.50 and 16.75 cents, respectively. Leaded zinc oxide of the 5 to 35 percent grade advanced 0.325 and 1.125 cents to a yearend quotation of 15.75 cents.

Zinc chloride (50° Baumé) was quoted at 5.25 cents per pound until September when it increased to 5.55 cents, where it remained for the balance of the year. Zinc sulfate (Monohydrate, 36 percent) in less than carlots was quoted at 9.50 cents per pound throughout the year.

Foreign Trade.—A substantial reduction in imports of zinc oxide exceeded increases for zinc chloride, zinc sulfate, and other compounds, resulting in a 25-percent decline for all zinc pigments and compounds.

TABLE 23.—Distribution of zinc sulfate shipments, by industries

(Short tons)

Year	Rayon		Agriculture		Other		Total	
	Gross weight	Dry basis	Gross weight	Dry basis	Gross weight	Dry basis	Gross weight	Dry basis
1955-59 (average)	19,515	17,450	8,369	7,231	4,934	3,999	32,818	28,680
1960	15,727	14,097	4,320	3,848	8,749	7,882	28,796	25,827
1961	12,284	11,007	5,673	5,086	10,934	9,926	28,891	26,019
1962	W	W	8,544	7,313	22,687	20,359	31,231	27,672
1963	W	W	10,785	9,407	29,326	23,674	40,111	33,081
1964	18,066	16,103	11,248	9,807	17,292	11,231	46,606	37,141

W Figure withheld to avoid disclosing individual company confidential data, included with "Other."

TABLE 24.—U.S. imports for consumption of zinc pigments and compounds

Kind	1963		1964	
	Short tons	Value (thousands)	Short tons	Value (thousands)
Zinc oxide	13,957	$2,532	8,708	$1,704
Zinc sulfide	423	133	393	123
Lithopone	159	22	172	21
Zinc arsenate	(1)	(1)	----------	----------
Zinc chloride	936	140	1,200	188
Zinc sulfate	885	84	1,245	123
Zinc cyanide	27	20	59	42
Zinc compounds, n.s.p.f.	115	23	653	188
Total	[r] 16,502	[r] 2,954	12,430	2,389

[r] Revised.
[1] Less than ½ unit.

Source: Bureau of the Census.

TABLE 25.—U.S. exports of zinc pigments

Kind	1963		1964	
	Short tons	Value (thousands)	Short tons	Value (thousands)
Zinc oxide	2,962	$827	2,435	$707
Lithopone	839	136	1,184	192
Total	3,801	963	3,619	899

Source: Bureau of the Census.

Canada and Mexico supplied 39 and 38 percent, respectively, of the zinc oxide imports.

Exports of zinc oxide declined 18 percent, with shipments to 40 countries. Lithopone exports increased by 41 percent, with Viet-Nam receiving 65 percent of the total.

STOCKS

Stocks of slab zinc at producer plants were 47,900 tons at the beginning of the year; they declined to a low of 26,000 tons at the end of July and then increased to 31,200 tons by December 31, the lowest yearend stocks recorded since 1951.

TABLE 26.—Stocks of zinc at zinc-reduction plants in the United States, Dec. 31

(Short tons)

	1960	1961	1962	1963	1964
At primary reduction plants	178,209	143,494	142,059	46,374	30,680
At secondary distilling plants	7,673	3,393	2,687	1,536	498
Total	185,882	146,887	144,746	47,910	31,178

Stocks of slab zinc at consumer plants of 97,500 tons at the start of the year were drawn down about 8,000 tons by the end of August, followed by at generally upward trend resulting in yearend stocks of 107,500 tons.

TABLE 27.—Consumer stocks of slab zinc at plants, Dec. 31, by industries

(Short tons)

Date	Galvanizers	Brass mills [1]	Zinc die-casters [2]	Zinc rolling mills	Oxide plants	Other	Total
Dec. 31, 1963	r 55,898	r 9,939	r 23,227	4,849	r 234	r 3,328	r [3] 97,475
Dec. 31, 1964	53,870	11,981	34,802	3,535	282	3,008	107,478

r Revised.

[1] Includes brass mills, brass ingot makers, and foundries.

[2] Includes producers of zinc-base alloy for diecastings, stamping dies, and rods.

[3] Stocks on Dec. 31, 1963, and Dec. 31, 1964, include 306 and 381 tons, respectively, of remelt spelter.

PRICES

The quoted price of Prime Western grade zinc, East St. Louis market, advanced one-half cent in April and 1 cent in October to reach a yearend price of 14.50 cents per pound.

About midyear, major producers outside the United States established a "producers' price" in reaction to a concern that the volatility and high prices on the London Metal Exchange might eventually adversely affect zinc consumption. During most of 1964, both the L.M.E. and "producers' price" were well above the U.S. price equivalent.

TABLE 28.—Average monthly quoted prices of 60-percent zinc concentrate at Joplin, and common zinc (prompt delivery or spot), East St. Louis and London[1]

Month	1963			1964		
	60-percent zinc concentrates in the Joplin region (per ton)	Metallic zinc (cents per pound)		60-percent zinc concentrates in the Joplin region (per ton)	Metallic zinc (cents per pound)	
		East St. Louis	London [2,3]		East St. Louis	London [2,3]
January	$68.00	11.50	8.45	$80.00	13.05	11.98
February	68.00	11.50	8.69	80.00	13.00	12.27
March	68.00	11.50	8.96	80.00	13.00	12.57
April	68.00	11.50	9.27	81.64	13.34	13.55
May	68.00	11.50	9.50	84.00	13.50	15.56
June	68.00	11.57	9.49	84.00	13.50	16.20
July	72.46	12.06	9.29	84.00	13.50	17.47
August	76.00	12.50	9.55	84.00	13.50	15.53
September	76.00	12.50	9.58	84.00	13.50	15.08
October	76.00	12.50	10.02	87.64	13.98	15.05
November	76.00	12.50	10.51	92.00	14.50	15.51
December	79.68	12.98	11.84	92.00	14.50	15.56
Average for year	72.01	12.01	9.60	84.44	13.57	14.74

[1] Joplin: Metal Statistics, 1965, p. 503. East St. Louis: Metal Statistics, 1965, p. 501. London: E&MJ Metal and Mineral Markets.

[2] Conversion of English quotations into U.S. money based on average rates of exchange recorded by Federal Reserve Board.

[3] Average of daily mean of bid and asked quotations at morning session of London Metal Exchange.

TABLE 29.—Average price received by producers of zinc, by grades

(Cents per pound)

Grade	1960	1961	1962	1963	1964
Special High Grade	13.68	11.58	11.43	11.66	14.17
High Grade	13.19	11.42	11.47	11.61	13.64
Intermediate	13.34	12.12	11.84	11.79	14.03
Brass Special	12.89	11.52	11.76	11.80	13.90
Select	12.64	11.60	12.88	11.29	13.55
Prime Western	12.15	11.32	11.45	11.35	12.97
All grades	12.85	11.45	11.47	11.55	13.64
Prime Western; spot quotation at St. Louis[1]	12.95	11.55	11.63	12.01	13.57

[1] Metal Statistics, 1965, p. 501.

During 1964, the quoted price for new clippings ranged from 7.50 to 10.00 cents per pound, averaging 8.68 cents. For old zinc, the quotation ranged from 4.25 to 6.25 cents and averaged 4.98 cents per pound.

FOREIGN TRADE

Import quotas imposed October 1, 1958, by Presidential Proclamation 3257, dated September 22, 1958, remained in effect through 1964. Quotas limited annual commercial imports of unmanufactured zinc (not including zinc fume) to 379,840 tons in ores and concentrates and 141,120 tons as metal. Quantitative country quotas are given in detail in the 1962 Minerals Yearbook chapter.

Imports.—In accordance with new Tariff Schedules of the United States, imports of ores and concentrates after August 31, 1963, are in terms of zinc content less certain allowable deductions for processing losses. Therefore, 1964 data are not exactly comparable with those of earlier years. For example, zinc concentrate assaying 55 percent zinc has approximately 89 percent of the contained zinc recorded as imported zinc; for zinc concentrate assaying 60 percent zinc there would be 90 percent of the contained zinc recorded as imported.

General imports (imports for immediate consumption plus entries into bonded warehouses) of zinc in ores and concentrates, as recorded, decreased 4 percent to 357,100 tons. However, using the factors described in the preceding paragraph, the indications are that on a metal content basis, the imports of ores and concentrates were somewhat larger in 1964 than in 1963. Zinc metal imports decreased 18 percent to 118,300 tons, the lowest level since 1952. Canada and Mexico supplied 75 percent of the total.

Imports for consumption (imports for immediate consumption plus withdrawals from bonded warehouses for consumption) were substantially lower than general imports for ores and concentrates and higher than general imports for metal.

Imports of zinc fume, not shown in the tables, were reported by the Bureau of the Census to have been 27,538 tons containing 23,696 tons of dutiable zinc. Mexico was the source of nearly all the fume.

TABLE 30.—U.S. imports of zinc, by countries

(Short tons)

Country	1955–59 (average)	1960	1961	1962	1963	1964
Ores (zinc content) [1]:						
North America:						
Canada	163,221	120,336	119,113	192,423	134,303	156,385
Guatemala	7,118	6,063	13,870	2,511	1,430	3
Honduras	1,834	4,714	6,851	7,048	8,234	7,709
Mexico	182,601	190,621	186,174	165,005	138,185	103,879
Other	1,297	78	---------	---------	---------	---------
Total	356,071	321,812	326,008	366,987	282,152	267,976
South America:						
Argentina	55	---------	---------	---------	---------	10,518
Bolivia	5,323	1,214	572	1,791	4,395	3,540
Chile	1,612	30	(2)	518	---------	1,741
Peru	98,224	80,100	74,369	77,501	73,788	62,864
Other	111	58	53	13	8	---------
Total	105,325	81,402	74,994	79,823	78,191	78,663
Europe:						
Germany, West	1,151	2	11	---------	---------	---------
Italy	2,953	---------	---------	---------	---------	---------
Spain	3,296	18,913	---------	---------	---------	---------
Other	2,011	100	109	19	---------	---------
Total	9,411	19,015	120	19	---------	---------
Asia:						
Philippines	442	4,774	3,203	24	9	7
Other	77	24	---------	---------	79	57
Total	519	4,798	3,203	24	88	64
Africa:						
South Africa, Republic of	13,831	12,300	7,551	9,589	8,614	6,086
Other	743	39	2	---------	---------	1,118
Total	14,574	12,339	7,553	9,589	8,614	7,204
Oceania: Australia	12,316	17,789	3,822	10,956	3,724	3,238
Grand total: Ores	498,216	457,155	415,700	467,398	372,769	357,145
Blocks, pigs, or slabs:						
North America:						
Canada	103,226	74,168	71,628	72,825	73,817	75,712
Mexico	18,552	8,950	8,598	12,334	13,219	12,791
Total	121,778	83,118	80,226	85,159	87,036	88,503
South America: Peru	12,275	7,517	7,519	7,615	7,574	7,569
Europe:						
Belgium-Luxembourg	22,727	5,724	12,854	23,232	21,904	5,807
Germany, West	6,685	2,680	779	1,162	6,103	265
Italy	8,662	3,517	1,820	992	907	---------
Spain	---------	2,986	6,756	2,572	6,270	2,723
United Kingdom	799	333	(2)	---------	1,183	682
Yugoslavia	4,167	4,520	3,198	3,310	1,185	441
Other	3,853	---------	561	640	440	1,025
Total	46,893	19,760	25,968	31,908	37,992	10,943
Asia: Japan	1,962	---------	---------	---------	---------	---------
Africa:						
Congo (Léopoldville)	19,960	9,307	11,420	10,882	9,590	10,878
Rhodesia and Malawi	2,759	615	1,400	4,643	1,982	62
Other	253	---------	---------	---------	---------	---------
Total	22,972	9,922	12,820	15,525	11,572	10,940
Oceania: Australia	6,488	450	1,029	1,750	583	385
Grand total: Blocks, pigs, or slabs	212,368	120,767	127,562	141,957	144,757	118,340

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[1] Zinc content less certain allowable deductions for processing losses, effective Sept. 1, 1963.
[2] Less than ½ unit.

Source: Bureau of the Census.

TABLE 31.—U.S. imports for consumption of zinc, by classes

Year	Ore (zinc content) [1]		Blocks, pigs, and slabs		Sheets		Old and worn out		Dross and skimmings		Zinc dust		Total value [2]
	Short tons	Value (thousands)	Short tons	Value (thousands)	Short tons	Value (thousands)	Short tons	Value (thousands)	Short tons	Value (thousands)	Short tons	Value (thousands)	
1955–59 (average)	497,655	$52,631	211,753	$49,024	694	$232	201	$30	516	$63	79	$17	$101,997
1960	382,938	38,704	120,925	29,639	904	302	106	14	1,099	175	19	7	68,841
1961	357,653	31,920	125,186	27,540	1,183	354	303	32	1,107	146	86	28	60,020
1962	387,321	31,817	135,995	28,478	1,303	365	861	120	1,907	286	909	207	61,273
1963	371,919	30,757	132,332	27,942	1,532	413	1,461	231	1,415	215	2,608	589	60,147
1964	311,435	35,831	134,118	31,898	1,774	527	1,274	227	2,501	425	3,269	797	69,705

[1] Zinc content less certain allowable deductions for processing losses, effective September 1, 1963.

[2] In addition, manufactures of zinc were imported as follows: 1955–59 (average) $388,701; 1960, $836,871; 1961, $787,496; 1962, $1,138,940; 1963, $978,619; 1964, $966,056.

Source: Bureau of the Census.

TABLE 32.—U.S. imports for consumption of zinc, by countries

(Short tons)

Country	1955–59 (average)	1960	1961	1962	1963	1964
Ores (zinc content)[1]:						
North America:						
Canada	164,452	133,080	110,312	135,430	131,125	117,866
Guatemala	7,557	1,811	7,244	8,375	3,692	6
Honduras	1,328	2,140	1,574	4,154	8,613	6,374
Mexico	192,059	142,478	140,057	139,374	138,419	105,059
Other	603	17	(2)	(2)	--------	--------
Total	365,999	279,526	259,187	287,333	281,849	229,305
South America:						
Argentina	23	--------	--------	--------	--------	12,442
Bolivia	4,576	790	1,018	681	3,492	2,084
Chile	1,843	5	7	216	324	--------
Peru	97,400	71,391	69,473	75,333	67,113	57,076
Other	57	94	81	22	30	--------
Total	103,899	72,280	70,579	76,252	70,959	71,602
Europe:						
Germany, West	1,460	--------	12	1	--------	--------
Italy	1,986	4,241	2,189	695	--------	--------
Spain	2,695	10,405	8,122	947	--------	--------
Other	1,295	982	--------	--------	--------	--------
Total	7,436	15,628	10,323	1,643	--------	--------
Asia:						
Philippines	469	679	4,426	2,663	43	16
Other	44	1	16	(2)	59	28
Total	513	680	4,442	2,663	102	44
Africa:						
South Africa, Republic of	10,337	5,333	6,218	10,391	11,438	6,384
Other	333	131	9	11	766	1,118
Total	10,670	5,464	6,227	10,402	12,204	7,502
Oceania: Australia	9,138	9,360	6,895	9,028	6,805	2,982
Grand total: Ores	497,655	382,938	357,653	387,321	371,919	311,435
Blocks, pigs, or slabs:						
North America:						
Canada	103,196	74,168	71,628	72,850	73,817	75,762
Mexico	18,374	8,675	8,527	12,334	12,619	12,794
Total	121,570	82,843	80,155	85,184	86,436	88,556
South America: Peru	12,275	7,517	7,582	7,615	7,574	7,519
Europe:						
Belgium-Luxembourg	22,776	5,724	12,380	16,829	16,070	14,668
Germany, West	6,674	1,619	1,431	1,889	1,585	2,939
Italy	8,558	4,237	1,820	992	907	--------
Spain	--------	2,809	4,560	2,429	4,666	4,993
United Kingdom	791	373	(2)	--------	623	575
Yugoslavia	3,893	5,640	3,277	2,750	1,564	909
Other	3,841	9	417	642	302	1,999
Total	46,533	20,411	23,885	25,531	25,717	26,083
Asia: Japan	1,967	--------	--------	--------	--------	--------
Africa:						
Congo (Léopoldville)	19,960	9,308	11,420	10,882	9,590	10,878
Rhodesia and Malawi	2,692	396	1,107	5,033	2,305	697
Other	312	--------	8	--------	--------	--------
Total	22,964	9,704	12,535	15,915	11,895	11,575
Oceania: Australia	6,444	450	1,029	1,750	710	385
Grand total: Blocks, pigs, or slabs	211,753	120,925	125,186	135,995	132,332	134,118

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[1] Zinc content less certain allowable deductions for processing losses, effective Sept. 1, 1963.
[2] Less than ½ unit.

Source: Bureau of the Census.

Exports.—Exports of slab zinc decreased 22 percent to 26,500 tons, the lowest level since 1959. India received 49 percent, the United Kingdom 18 percent, and South Korea 7 percent of total exports.

TABLE 33.—U.S. exports of slab and sheet zinc, by countries

(Short tons)

Destination	Slabs, pigs, and blocks				Sheets, plates, strips, or other forms, n.e.s.			
	1961	1962	1963	1964	1961	1962	1963	1964
North America:								
Canada	382	495	337	53	1,356	1,512	1,541	2,652
Mexico	--------	1	--------	216	56	21	25	23
Other	19	16	16	51	65	80	60	88
Total	401	512	353	320	1,477	1,613	1,626	2,763
South America:								
Argentina	61	--------	--------	51	35	36	48	30
Brazil	4,598	262	128	--------	27	12	15	25
Chile	314	39	163	331	36	43	35	42
Colombia	404	--------	663	565	55	213	37	53
Venezuela	161	7	13	325	78	119	86	111
Other	233	110	1	1	18	24	12	28
Total	5,771	418	968	1,273	249	447	233	289
Europe:								
Belgium-Luxembourg	--------	--------	--------	--------	21	20	34	34
Denmark	56	--------	--------	55	173	164	230	180
Germany, West	336	2	14	224	63	32	59	1,172
Italy	224	--------	--------	--------	33	29	113	124
Netherlands	2,252	--------	--------	--------	170	127	123	186
Sweden	1,993	--------	--------	--------	140	231	227	215
Switzerland	--------	--------	--------	--------	165	221	205	152
United Kingdom	12,265	112	--------	4,837	335	242	261	254
Other	1,806	733	--------	736	229	228	369	601
Total	18,932	847	14	5,852	1,329	1,294	1,621	2,918
Asia:								
India	10,490	32,625	30,155	13,066	10	19	16	28
Japan	7,353	1	147	662	29	--------	--------	2
Korea, South	3,139	903	1,969	1,900	1	1	8	81
Philippines	1,685	10	6	938	22	37	31	60
Other	2,274	680	163	2,056	9	40	86	255
Total	24,941	34,219	32,440	18,622	71	97	141	426
Africa:								
South Africa, Republic of	--------	--------	--------	--------	76	80	89	104
Other	8	106	78	448	4	3	6	32
Total	8	106	78	448	80	83	95	136
Oceania	2	--------	--------	--------	13	13	40	37
Grand total	50,055	36,102	33,853	26,515	3,219	3,547	3,756	6,569

Source: Bureau of the Census.

Tariff.—Duties on unmanufactured zinc and zinc containing materials remained unchanged and were as follows: Slab zinc, 0.7 cent per pound; zinc ores and concentrates, 0.67 cent per pound; zinc scrap, 0.75 cent per pound; zinc fume, 15 percent ad valorem; and zinc dust, 0.7 cent per pound.

TABLE 34.—U.S. exports of zinc ore and manufactures of zinc

Year	Zinc ore, concentrates (zinc content)		Slabs, pigs, or blocks		Sheets, plates, strips, or other forms, n.e.s.		Zinc scrap and dross (zinc content)		Semifabricated forms, n.e.c.		Zinc dust	
	Short tons	Value (thousands)	Short tons	Value (thousands)	Short tons	Value (thousands)	Short tons	Value (thousands)	Short tons	Value (thousands)	Short tons	Value (thousands)
1955–59 (average)	172	$32	10,274	$2,514	3,901	$2,704	11,735	$1,206	2,791	$399	490	$169
1960	13	3	75,144	18,122	3,324	2,443	12,169	1,499	2,569	1,195	777	267
1961	1,670	124	50,055	11,196	3,219	2,271	5,900	871	3,036	1,317	717	224
1962	136	46	36,102	8,050	3,547	2,391	7,940	956	1,613	1,254	676	240
1963	17	6	33,853	7,506	3,756	2,742	1,794	539	1,532	1,163	759	261
1964	39	12	26,515	7,240	6,569	3,978	6,448	1,379	5,666	2,451	1,828	542

WORLD REVIEW

NORTH AMERICA

Canada.—Mine production increased 44 percent to a record 730,000 tons of zinc in concentrates to make Canada the world's largest producer of zinc. The increase was largely attributed to the recent development of mines in the Mattagami district of Quebec and in New Brunswick. Slab zinc output also increased to a record 338,000 tons. The increase was principally due to completion of the first full year of operation at the zinc plant at Valleyfield, Quebec. The annual zinc productive capacity of zinc plants in 1964 totaled 359,000 tons—208,000 tons for Consolidated Mining & Smelting Co. of Canada, Ltd. (Cominco), 79,000 tons for Hudson Bay Mining & Smelting Co., Ltd. and 72,000 tons for Canadian Electrolytic Zinc, Ltd.[8]

TABLE 35.—World mine production of zinc (content of ore) recoverable where indicated, by countries [1] [2] [3]

(Short tons)

Country [2]	1955–59 (average)	1960	1961	1962	1963	1964 [p]
North America:						
Canada	418,168	[4] 406,873	[5] 443,099	[5] 501,937	[5] 497,180	[5] 729,939
Cuba	765	[6] 77	-----	-----	-----	-----
Greenland [e]	[7] 7,600	11,000	8,800	4,400	-----	-----
Guatemala [4]	9,531	11,069	8,746	899	1,289	-----
Honduras [6]	1,834	4,713	6,851	7,048	8,234	7,708
Mexico	275,435	289,274	296,492	276,330	264,354	269,992
United States [4]	485,211	435,427	464,390	505,491	529,254	574,858
Total	1,198,544	1,158,433	1,228,378	1,296,105	1,300,311	1,582,497
South America:						
Argentina	33,422	39,022	35,502	34,686	31,636	25,253
Bolivia (exports)	16,685	4,439	5,878	4,021	5,124	10,755
Chile	2,274	1,159	179	547	557	1,272
Colombia [e]	[8] 770	330	1,400	300	100	110
Peru	170,641	[4] 196,346	[4] 191,658	[4] 178,839	[4] 216,392	[4] 254,595
Total	223,792	241,296	234,617	218,393	253,809	291,985

See footnotes at end of table.

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[8] Fraser, D. B. Miner. Res. Division, Dept. of Mines and Tech. Surveys (Ottawa, Canada), Miner. Inf. Bull. MR 79, 1965, p. 28.

TABLE 35.—World mine production of zinc (content of ore) recoverable where indicated, by countries [1] [2] [3]—Continued

(Short tons)

Country [2]	1955–59 (average)	1960	1961	1962	1963	1964 [p]
Europe:						
Austria [4]	6,195	7,250	6,651	7,264	7,816	8,004
Bulgaria	53,374	84,878	81,461	88,736	81,130	[e] 89,600
Finland	44,975	46,328	51,363	57,509	73,142	69,436
France	14,731	18,933	17,284	15,735	20,060	18,651
Germany:						
East [e]	7,700	7,700	7,700	8,800	11,000	11,000
West	98,454	95,159	96,189	95,991	102,722	105,627
Greece	11,817	16,204	19,342	18,939	20,062	19,842
Hungary	1,819	2,315	2,425	2,535	2,866	[e] 2,866
Ireland	1,625	1,377	184	---	---	---
Italy	142,027	143,985	150,315	145,596	117,979	128,419
Norway	8,616	11,395	10,285	12,566	13,669	13,062
Poland	155,845	158,843	153,857	159,961	162,150	166,669
Portugal	231	---	---	12	190	1,049
Spain	94,475	94,920	96,983	86,554	101,118	98,499
Sweden	75,299	81,824	87,558	90,227	89,728	78,925
U.S.S.R. [e]	[9] 325,000	[4] 415,000	[4] 440,000	[4] 450,000	[4] 450,000	[4] 450,000
United Kingdom	1,524	---	---	---	---	---
Yugoslavia	65,267	62,150	66,009	67,367	67,534	72,830
Total [e] [3]	1,109,000	1,248,000	1,288,000	1,308,000	1,321,000	1,334,000
Asia:						
Burma	10,300	11,000	8,100	9,000	8,900	8,900
China [e]	46,900	88,000	110,000	110,000	110,000	110,000
India	4,409	5,952	5,622	6,099	6,460	6,520
Iran [10]	6,760	9,370	14,880	8,270	[e] 11,000	[e] 16,500
Japan	143,958	172,769	185,474	212,174	218,209	237,602
Korea:						
North [e]	80,000	95,000	100,000	100,000	110,000	110,000
South	[7] 281	46	496	463	1,245	2,800
Philippines	462	5,487	3,652	4,916	4,291	2,355
Thailand [e]	1,775	1,168	992	[e] 1,000	942	1,521
Turkey	5,603	3,682	9,127	6,801	5,044	[e] 2,048
Total [e]	300,000	392,000	438,000	459,000	476,000	498,000
Africa:						
Algeria	36,785	44,240	46,448	46,215	40,000	38,932
Congo, Republic of (Brazzaville)	---	661	1,411	786	786	5,578
Congo, Republic of the (Léopoldville)	105,179	120,352	109,828	105,530	114,139	116,338
Morocco	52,731	54,199	44,951	37,942	36,418	47,950
South-West Africa [4]	19,196	13,119	14,905	25,201	36,715	35,311
Tunisia	4,720	4,697	4,596	4,727	4,809	3,585
Zambia	40,218	49,242	45,084	45,084	42,108	51,491
Total	258,829	286,510	267,223	265,485	274,975	299,185
Oceania: Australia	[11] 312,549	355,497	348,496	378,036	393,600	387,353
World total [e]	3,405,000	3,680,000	3,805,000	3,925,000	4,020,000	4,395,000

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[e] Estimate. [p] Preliminary.

[1] Data derived in part from the Yearbook of the American Bureau of Metal Statistics, the UnitedNation, Statistical Yearbook, and the Statistical Summary of the Mineral Industry (Overseas Geological Surveys London).

[2] Czechoslovakia and Rumania also produce zinc, but production data are not available; no estimates are included in totals.

[3] This table incorporates some revisions. Data do not add exactly to totals shown because of rounding where estimated figures are included in the detail.

[4] Recoverable.

[5] Data for 1961, 1962, 1963, and 1964 not strictly comparable to previous years.

[6] United States imports.

[7] Average annual production 1956–59.

[8] Average for 1 year only, as 1959 was the first year of commercial production.

[9] Smelter production.

[10] Year ended Mar. 20 of year following that stated.

[11] Data for 1955–57 not strictly comparable with later years.

TABLE 36.—World smelter production of zinc by countries[1,2,3]

(Short tons)

Country	1955–59 (average)	1960	1961	1962	1963	1964 [p]
North America:						
Canada	253,364	260,968	268,007	280,158	284,021	337,728
Mexico [4]	62,212	58,318	57,119	62,730	62,557	65,506
United States	902,564	799,516	846,795	879,395	892,584	954,084
Total	1,218,140	1,118,802	1,171,921	1,222,283	1,239,162	1,357,318
South America:						
Argentina	15,823	17,637	15,873	18,487	21,716	24,471
Peru	24,666	35,712	35,006	36,309	60,312	65,854
Total	40,489	53,349	50,879	54,796	82,028	90,325
Europe:						
Austria	8,804	12,700	13,302	13,325	13,074	14,215
Belgium [5]	246,330	272,891	270,670	227,248	227,437	245,308
Bulgaria	7,064	18,639	24,385	57,017	61,800	64,595
France	143,959	168,822	183,918	186,471	189,720	213,848
Germany:						
East	----------	----------	1,102	5,512	[e] 11,000	[e] 11,000
West	180,680	156,299	155,373	143,127	115,969	117,988
Hungary	705	772	1,323	1,653	1,213	[e] 1,200
Italy	79,732	88,040	87,647	85,618	81,093	80,077
Netherlands	32,228	39,771	43,643	40,839	39,421	41,557
Norway	52,237	48,460	51,287	49,576	51,419	53,306
Poland	176,138	193,501	200,633	199,935	199,739	206,022
Spain	26,018	49,565	57,865	68,981	71,353	69,486
U.S.S.R. [e]	330,000	435,000	470,000	515,000	515,000	510,000
United Kingdom	86,745	83,220	104,031	108,949	110,911	122,396
Yugoslavia	27,841	39,612	40,640	43,325	46,566	49,066
Total [e] [1]	1,398,000	1,607,000	1,706,000	1,747,000	1,736,000	1,800,000
Asia:						
China (refined) [e]	45,000	75,000	100,000	100,000	100,000	100,000
Japan	151,488	198,920	234,163	270,402	291,382	314,988
Korea, North [e]	[6] 18,000	55,000	65,000	65,000	70,000	70,000
Total [e]	214,000	329,000	399,000	435,000	461,000	485,000
Africa:						
Congo, Republic of the (Léopoldville)	51,477	58,817	62,788	61,759	58,118	61,237
Zambia	32,908	33,369	33,444	44,576	54,510	51,491
Total	84,385	92,186	96,232	106,335	112,628	112,728
Oceania: Australia	122,676	134,658	155,338	188,079	201,350	207,794
World total [e]	3,080,000	3,335,000	3,580,000	3,755,000	3,830,000	4,055,000

[e] Estimate. [p] Preliminary.

[1] Czechoslovakia and Rumania also produce zinc, but production data are not available; no estimates are included in the totals.

[2] Data derived in part from the Yearbook of the American Bureau of Metal Statistics, the United Nations Monthly Bulletin and Statistical Yearbook, and the Statistical Summary of the Mineral Industry (Overseas Geological Surveys, London).

[3] This table incorporates some revisions. Data do not add exactly to totals shown because of rounding where estimated figures are included in the detail.

[4] In addition, other zinc-bearing materials were as follows: 1955–59 (average), 25,500 short tons; 1960, 1,246; 1961, 1,992; 1962, 1,890; 1963, 3,400; and 1964, 3,839.

[5] Includes production from reclaimed scrap.

[6] Average annual production 1957–59.

Cominco recorded zinc metal production of 199,011 tons, only slightly below the 1962 record high of 199,393 tons. The combined zinc-lead production derived approximately 68 percent from the company's Sullivan mine, 14 percent from other company mines, 17 percent from purchased ores and concentrates, and 1 percent from lead-blast furnace slag. Extraction of ore from company properties was 2,711,000 tons at the Sullivan mine (2,595,000 tons in 1963), 258,000 tons from the Bluebell lead-zinc mine (256,000 tons in 1963), and 478,000 tons at the H. B.

mine (474,000 tons in 1963). Commencing in November, test shipments of zinc-lead ore from the company's new development at Pine Point were treated in the Sullivan mill. Ore reserves at company mines tributary to the Trail smelter (Sullivan, Bluebell, and H. B.) at September 30 totaled 75.6 million tons containing 8.3 million tons of lead and zinc.[9]

According to the anuual report of Reeves MacDonald Mines, Ltd., the company mined and milled 379,000 tons of ore at its Remac, British Columbia, mine and produced concentrates containing 12,958 tons of zinc plus values in lead, silver, and cadmium. Operations were at near capacity following the December 1963 termination of an 8-month strike.

Sheep Creek Mines, Ltd., Windermere, British Columbia, reported production at the Mineral King property for the year ending May 31, 1964, to have been 194,400 tons of ore grading 4.62 percent zinc and 1.87 percent lead. Milling yielded 13,767 tons of 56.79 percent zinc concentrate plus recovered lead and silver. Reserves at the end of the year totaled 351,000 tons of ore, compared with 403,000 tons at the start of the year.[10]

Hudson Bay Mining & Smelting Co., Ltd., operated its zinc-copper-lead mines along the Manitoba-Saskatchewan boundary. The mill treated 1,585,000 tons of ore—49.9 percent from the Flin Flon mine, 48.8 percent from other company mines, and 0.3 percent purchased—which yielded 103,234 tons of 47.8 percent zinc concentrates plus copper and lead concentrates. Exploration disclosed more ore than was mined during the year, and proven reserves at yearend totaled 16.6 million tons averaging 4.3 percent zinc. The electrolytic plant at Flin Flon treated 115,122 tons of zinc concentrate and 47,479 tons of zinc fume and stack dust from the copper smelter to produce 71,012 tons of slab zinc.[11]

Willroy Mines, Ltd., at its Manitouwadge, Ontario, operation milled 530,200 tons of ore averaging 3.33 percent zinc, 1.13 percent copper, 0.12 percent lead, and 1.37 ounces of silver per ton. The concentrates produced contained 15,353 tons of zinc and quantities of copper and silver. Development included drifting 2,337 feet towards the Nama Creek mine, drilling the lower mine horizons, and drilling 12,342 feet on other claims. The ore reserve at yearend was 1.1 million tons, averaging 3.03 percent zinc, 1.36 percent copper, and 1.04 ounces of silver per ton.[12]

Geco Mines, Ltd., amalgamated December 15 with Noranda Mines, Ltd., operated the Geco mine at Manitouwadge, Ontario, during 1964. The mill treated 1,299,000 tons of ore with a calculated grade of 5.52 percent zinc, 2.09 percent copper, and 2.48 ounces of silver per ton. The ore yielded concentrates containing 56,639 tons of zinc, a decrease of 5 percent from the quantity produced in 1963. Exploration added a net increase of 963,000 tons of ore to a yearend total reserve of 23 million tons, averaging 4.45 percent zinc, 2.09 percent copper, and 2.25 ounces of silver per ton.[13]

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[9] Consolidated Mining & Smelting Co. of Canada, Ltd. Annual Report. 1964, pp. 4–6.
[10] Sheep Creek Mines, Ltd. Annual Report. 1964, 11 pp.
[11] Hudson Bay Mining & Smelting Co., Ltd. Annual Report. 1964, pp. 10–15.
[12] Willroy Mines, Ltd. Annual Report. 1964, pp. 2–3.
[13] Noranda Mines, Ltd. Annual Report. 1964, 24 pp.

In Quebec, Quemont Mining Corp., Ltd., milled 753,000 tons of ore grading 2.38 percent zinc plus values in copper, silver, gold, and pyrite, yielding 25,522 tons of 53.2 percent zinc concentrate. Reserves at yearend were estimated to total 2,290,000 tons, averaging 2.61 percent zinc.[14] According to its annual report for the year ending August 31, 1964, Solbec Copper Mines, Ltd., mined and milled 369,000 tons of ore yielding concentrates containing 12,578 tons of zinc plus values in copper, lead, gold, and silver. The reserve at yearend was 1,033,000 tons, averaging 4.46 percent zinc, 1.83 percent copper, 0.66 percent lead, and 1.54 ounces of silver per ton. Cupra Mines, Ltd., completed sinking a 2,250-foot shaft and continued development towards scheduled production by September 1965. The ore reserve to a depth of 1,400 feet was 1.0 million tons, with an average grade of 3.25 percent copper, 3.03 percent zinc, 0.51 percent lead, and 1.18 ounces of silver per ton.[15] Sullico Mines, Ltd., mined and milled 991,000 tons of ore yielding concentrates containing 2,568 tons of zinc. Reserves at yearend amounted to 1,177,000 tons grading 0.70 percent copper and 0.19 percent zinc.[16] Normetal Mining Corp., Ltd., mined and milled 349,000 tons of ore yielding concentrates containing 21,641 tons of zinc plus quantities of copper, gold, and silver.[17]

In the Mattagami Lake district of Quebec, Mattagami Lake Mines, in its first full year of production, milled 1,282,000 tons of ore averaging 12.8 percent zinc and 0.7 percent copper to produce 275,674 tons of 52.8 percent zinc concentrate. Orchan Mines, Ltd., in its first full year, milled 369,000 tons of ore yielding concentrates containing 40,190 tons of zinc. Concentrates from both mills were shipped to the zinc reduction plant of Canadian Electrolytic Zinc at Valleyfield, Quebec, which began operations in late September 1963. Slab zinc production was 67,710 tons, with the rated daily output of 200 tons scheduled to be increased to 300 tons by late 1965.[18]

Other Quebec producers of zinc included Coniagas Mines, Manitou-Barvue Mines, Vauze Mines, and Lake Default Mines which began operation of a 1,300-ton mill in the Noranda district in August.

In the Atlantic Provinces, Heath Steele Mines, Ltd., mined and milled zinc-lead-copper ore from its mine near Bathurst, New Brunswick. Magnet Cove Barium Corp., Ltd., produced a zinc-silver concentrate in its 120-ton mill at Walton, Nova Scotia. Brunswick Mining and Smelting Corp., Ltd., brought its zinc-lead-copper Brunswick No. 12 mine into production in March and through September produced 71,638 tons of 49.5 percent zinc concentrate. The Associated East Coast Smelting and Chemical Co. continued construction of a lead-zinc Imperial Smelting Furnace scheduled for completion in 1966 for treatment of the concentrates.[19]

In Newfoundland, Buchans Mining Co., Ltd., milled 383,000 tons of ore, yielding 115,644 tons of copper, lead, and zinc concentrates. Two-thirds of the output was from the McLean mine, and the balance, from the Buchans mine.[20]

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[14] Quemont Mining Corp., Ltd. Annual Report. 1964, p. 3.

[15] Cupra Mines, Ltd. Annual Report. 1964, p. 39.

[16] Sullico Mines, Ltd. Annual Report. 1964, p. 21.

[17] Noranda Mines, Ltd. Annual Report. 1964, p. 18.

[18] Noranda Mines, Ltd. Annual Report. 1964, p. 23.

[19] Fraser, D. B. Miner. Res. Division, Dept. of Mines and Tech. Surveys (Ottawa, Canada), Miner. Inf. Bull. MR–79, 1965, p. 31.

[20] American Smelting and Refining Co. Annual Report. 1964, p. 14.

Mexico.—Zincamex, S. A., a company formed by the Mexican Government, completed construction and started operating a zinc reduction plant at Saltillo, Coahuila. The facility was designed for annual slab zinc output of 30,000 tons.

Compañia Minera Asarco, S.A., wholly owned subsidiary of American Smelting and Refining Co., operated its mines and plants in Mexico without interruption during 1964. The company continued efforts to Mexicanize Compañia Minera Asarco to permit qualification for tax benefits provided under the Mining Law of 1921.[21]

Metalurgica Mexicana Penoles, S.A. (49 percent owned by American Metal Climax, Inc.) continued to operate its lead-zinc properties in Mexico.

According to the annual report of San Francisco Mines of Mexico, Ltd., for the year ending June 30, 1964, a total of 918,000 tons of ore was milled from the company's San Francisco and Clarines mines which produced 104,500 tons of 56.16 percent zinc concentrate plus values in lead, copper, silver, and gold. The ore reserve at the end of the fiscal year was 6 million tons, averaging 7.72 percent zinc, 5.30 percent lead, and 0.53 percent copper.

The Fresnillo Co. operated lead-zinc mining and milling units at Fresnillo in Zacatecas and at Naica in Chihuahua. In the year ending June 30, 1964, the company milled a total of 1,105,000 tons of ore. The Fresnillo mill produced 31,044 tons of 52.0 percent zinc concentrate, and the Naica mill produced 43,714 tons of 54.0 percent zinc concentrate. The company also mined lead-zinc at its Zimapan Unit in Hidalgo, and had 30,000 tons of ore treated by a custom flotation mill. This ore yielded 3,423 tons of 51.8 percent zinc concentrate. Ore reserves at yearend at the Fresnillo and Naica mines totaled 4,551,000 tons containing 4.8 percent zinc, 5.0 percent lead, and 5.2 ounces of silver per ton.[22]

SOUTH AMERICA

Argentina.—Cia. Minera Aguilar, S.A., a subsidiary of St. Joseph Lead Co., continued operation of a lead-zinc-silver mine in the Province of Juyjuy in northern Argentina and through affiliated companies operated a zinc smelter and electrolytic zinc plant. The square-set and cut-and-fill stoping methods used have been briefly described.[23]

Peru.—Cerro de Pasco Corp. produced a record 67,101 tons of slab zinc from concentrates of its own mines. In addition, 68,558 tons of zinc in concentrates were sold for export. An extensive development program was initiated at the McCune Pit to enlarge the lead-zinc operations. Funds were appropriated to complete in 1966 the conversion of the Yauricocha mine from production of direct smelting copper ore to a zinc-lead-copper-silver concentrating ore. Cerro's La Aroya electrolytic zinc plant will be expanded by mid-1966 to an annual capacity of 75,000 tons.[24]

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[21] American Smelting and Refining Co. Annual Report. 1964, pp. 14–15.

[22] The Fresnillo Co. Annual Report. 1964, pp. 12–14.

[23] Engineering and Mining Journal. Progress in South America. V. 165, No. 4, April 1964, pp. 115–117.

[24] Cerro Corp. Annual Report. 1964, p. 3–4.

Cia. Minerales Santander, Inc., a St. Joseph Lead Co. subsidiary, operated an open pit lead-zinc-silver mine in the Peruvian Andes. Other zinc producers included Cia. Minera Atacocha, S.A., Cia des Mines de Huaron, Cia Minera Milpo, Northern Peru Mining Corp., and Volcan Mines Co. The Chavin Mines Corp. was developing a lead-zinc property with 200-ton-per-day milling rate scheduled for mid-1965.

EUROPE

Finland.—The Vihanti mine continued as the leading zinc producer in Finland, yielding 92,481 tons of 55.0 percent zinc concentrate from 515,000 tons of ore. The Pyhasalmi copper-zinc mine produced 31,228 tons of 55.6 percent zinc concentrates from 681,000 tons of ore.

France.—Société Minièrè et Metallurgique de Penarroya, S.A., proved large lead-zinc reserves in the Largentiere district in the south of France. The company started recovery of lead in midyear and in the future plans addition of a zinc flotation circuit to recover zinc.

Germany, West.—West German Government officials accepted the decision of the European Economic Community Commission to eliminate lead and zinc subsidies during 1964. However, the West German Government reserved the right to resume support of the industry if there should be a deterioration in the lead and zinc market.

Ireland.—Development of nonferrous metal properties continued at a rapid pace during the year. Irish Base Metals, Co., Ltd., a subsidiary of Northgate Exploration, Ltd., completed financing and set a target date of September 1, 1965, for a 2,000-ton-per-day ore production from its lead-zinc-silver mineral deposit at Tynagh. Mogul of Ireland, Ltd., formed by Consolidated Mogul Mines, Ltd., and Silvermines Lead and Zinc Co., Ltd., explored its Silvermine property and proved a reserve of 10 million tons of 2.5 percent lead, 8.16 percent zinc, and 0.8 ounce of silver per ton. First steps have been taken toward production with a considered milling rate of 3,000 tons per day. A subsidiary exploration company of The Rio Tinto-Zinc Corp., Ltd., reported discovery of a lead-zinc deposit about 45 miles northeast of Tynagh. Other major base metals companies are also exploring in Ireland.[25]

Sweden.—Mines of the Boliden Mining Co., Ltd., yielded 90,100 tons of zinc concentrate. A new slag fuming plant treating copper-furnace slag started up during the year and produced 14,800 tons of zinc fume. Capacity of this plant is estimated at 25,000 tons. Exploration of a zinc-lead-pyrite ore deposit at a site known as the Langdal mine proved sufficient reserves to schedule production for 1967.[26]

United Kingdom.—Production of slab zinc increased for the fifth consecutive year to a record 122,000 tons. Almost all of the increase was due to an advance of 28 percent in output at the Imperial Smelting Furnace at Swansea which throughout 1964 utilized enrichment of blast air with oxygen to boost production. Vacuum distillation equipment, developed at Avonmouth, will be added to permit production of higher grades of metal during 1966.[27]

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[25] Mining Journal (London). Annual Review. 1964. pp. 282–283.
[26] Boliden Mining Co., Ltd. Annual Report. 1964, pp. 2–5.
[27] The Rio Tinto-Zinc Corp. Ltd. Annual Report. 1964, p. 33.

ASIA

Burma.—The Burma Corp., Ltd., was considering reopening its Bawdwin lead-zinc-silver mine. A study financed by the United Nations Special Fund and the Burmese Government disclosed reserves for a least 20 years of operation at twice the previous production rate.[28]

India.—Cominco-Binani Zinc Ltd., a joint venture of Metal Corporation of India, Ltd., and The Consolidated Mining & Smelting Co. of Canada, Ltd., continued work on design, site preparation, and initial construction of an electrolytic zinc plant near Cochin in Kerala State. The completion is expected during the second half of 1966, with a planned capacity of 22,000 tons of zinc per year.[29]

Japan.—Three companies within the Sumitomo industrial group are planning to build a vertical blast furnace smelter with an annual capacity of 36,000 tons of zinc and 18,000 tons of lead. Part of the raw materials requirement would be met by importation of 40,000 tons of zinc concentrates per year from Australia.

Philippines.—Benguet Exploration, Inc., was constructing a 30-ton-per-day mill circuit to recover zinc concentrates from a 36,000-ton ore zone averaging 11.2 percent zinc and 0.25 ounce of gold per ton.

Turkey.—A comprehensive report on the geology and ore deposits, and the mining, milling, and smelting operations relating to the lead and zinc industry of Turkey was prepared. The report concludes that ample lead-zinc reserves could be developed in Turkey to greatly expand the present production.

AFRICA

Algeria.—Five lead-zinc mines operated in 1964, with the El Abed and Oued Zounder mines near the Moroccan border the largest producers. El Abed output remained below pre-1963 levels, and indications are that the reserve is being exhausted. The Ouarsenis mine near Algiers increased output of zinc carbonate concentrate from 1,700 to 5,400 tons.

Congo (Léopoldville).—Union Miniere du Haut-Katanga's Kipushi concentrator milled 1,140,000 tons of copper-zinc ore to produce 197,000 tons of 59.0 percent zinc concentrate. A subsidiary of the company, Societe Generale Industriell et Chimique du Katanga, roasted 134,000 tons of the zinc concentrate, producing sulfuric acid and 112,000 tons of roasted concentrate. During the year, 106,000 tons of roasted concentrate was sold to Societe Metallurgique du Katanga (Matalkat) for reduction to zinc and 85,000 tons of raw and roasted concentrates were delivered for export. Metalkat produced 61,247 tons of electrolytic zinc.[30]

Malawi, Southern Rhodesia, and Zambia.—The production of zinc by the Rhodesia Broken Hill Development, Co., Ltd. decreased in 1964, largely because of a strike from February 17 to March 22. Other factors causing the decline were a rail strike interfering with delivery of coke and operating difficulties at the company's vertical lead-zinc blast furnace.

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[28] Engineering and Mining Journal. V. 166, No. 1, January 1965, pp. 120–121.
[29] The Consolidated Mining & Smelting Co. of Canada, Ltd. Annual Report. 1964, p. 19.
[30] Union Miniere du Haut-Katanga. Annual Report. 1964, 44 pp.

South-West Africa.—Tsumeb Corp., Ltd., in the year ending June 30, 1964, mined and milled, at the Tsumeb property, 748,000 tons of complex copper-lead-zinc sulfide and oxide ore averaging 3.75 percent zinc. Zinc sold and taken into account was 8,971 tons, compared with 9,491 tons in 1963.[31]

OCEANIA

Australia.—The Broken Hill district of New South Wales continued to be the leading Australian zinc-producing area. Mining companies operating and ranked in order of their output were New Broken Hill Consolidated, Ltd.; The Zinc Corporation, Ltd.; North Broken Hill, Ltd.; and Broken Hill South, Ltd. Combined output was 2,650,000 tons of zinc-lead-silver ore, yielding 517,000 tons of zinc concentrate averaging 52.9 percent zinc.

Sulphide Corp. Pty., Ltd., operated its Imperial Smelting type furnace at Cockle Creek, New South Wales. Output increased 10 percent for slab zinc to 53,700 tons and 12 percent to 25,900 tons for lead bullion.[32]

Mount Isa Mines, Ltd., during the fiscal year ended June 30, 1964, milled 4,105,000 tons of silver-lead-zinc ore and produced 28,849 tons of zinc in concentrates. The assured reserves at yearend were 30,350,000 tons of ore averaging 7.8 percent lead, 5.9 percent zinc, and 5.6 ounces of silver per ton. The new K57 mine shaft was completed to the final depth of 3,753 feet and construction of the new 6,000-ton-per-day concentrator was well advanced by the end of 1964. A labor slowdown commenced in August and resulted in complete closure December 15.[33]

The Electrolytic Zinc Co. of Australasia, Ltd., produced a record 154,100 tons of slab zinc at its Risdon, Tasmania, electrolytic plant during the fiscal year ending June 30, 1964, compared with 151,500 tons in 1963. The company's mining-milling operations in the Read-Rosebery district milled a record 337,000 tons of ore yielding 123,000 tons of zinc, lead, and copper concentrates, each an increase of 7 percent.[34]

New Zealand.—North Island Mines and South Pacific Mines announced exploration of a mineral deposit containing at least 100,000 tons of ore grading 15 percent zinc and 5 percent lead. Development was planned to begin mining at a rate of about 100 tons per day by late 1965.

TECHNOLOGY

A comprehensive coverage of zinc technology reported in the scientific and technical press is included in the 1,802 items contained in the monthly issues of the 1964 Zinc Abstracts, jointly published by the Zinc Development Association (London) and the American Zinc Institute.

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[31] Newmont Mining Corp. Annual Report. 1964, p. 7.
[32] The Rio Tinto-Zinc Corp. Ltd. Annual Report. 1964, p. 28.
[33] American Smelting and Refining Co. Annual Report. 1964, pp. 16–17.
[34] E Z Industries, Ltd. Annual Report. 1964, p. 4.

The International Lead-Zinc Research Organization (ILZRO) continued the sponsorship of numerous projects to develop fundamental knowledge or particular applications of zinc or zinc containing materials. Progress reports of these projects are released biannually by means of the ILZRO Research Digest.

Results of several research investigations were published by the Bureau of Mines [35] and U.S. Geological Survey.[36]

Representative of the many published results of research were several papers relating to ore discovery.[37] Articles on extractive metallurgy described operating experience in the refining of zinc in a vertical retort [38] in production of electrolytic zinc,[39] and in recovery of zinc from copper-zinc concentrates by hydrometallurgy.[40]

An article described features employed in continuous strip galvanizing plants to efficiently produce a full range of products,[41] and another article reported on characteristics of available zinc coatings.[42] Patents were granted on several ways to apply a protective coating to a zinc surface,[43] and on a method for producing a zinc coating on a titanium-containing steel base without formation of iron-zinc metallic compounds.[44]

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Taylor, A. R. Geology of the Rewey and Mifflin Quadrangles, Wisconsin. Geol. Survey Bull. 1123–F, 1964, pp. 279–360.

[37] Baxter, Robert A., and Stewart E. Post. Geochemical Prospecting. Mines Mag., v. 54, No. 9, September 1964, pp. 27–28.

Proctor, Paul Dean. Fringe Zone Alteration in Carbonate Rocks, North Tintic District, Utah. Econ. Geol., v. 59, No. 8. December 1964, pp. 1564–1595.

[38] Healey, R., and V. E. Clifton. Some Recent Developments in the Construction of Vertical Zinc Retorts at Avonmouth. Bull. Inst. Min. & Met. (London), v. 73, part 11, No. 693, August 1964, pp. 779–794.

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[41] Turner, Charles A. Advantages of Direct-Fired Heating in Continuous Strip Galvanizing. Iron and Steel Eng., v. 61, No. 3, March 1964, pp. 107–113.

[42] Daesen, John R. Choose the Right Zinc Coating for Large Structures. Metal Prog., v. 86. No. 3, September 1964, pp. 95–100.

[43] Harris, Brian W., and Edgar J. Seyb, Jr. (assigned to M & T Chemicals Inc., New York). Process for Providing a Chromate Coating on Zinc and Cadmium Surface. U.S. Pat. 3,147,153, Sept. 1, 1964.

Hines, William G., and Ramon L. Addinall (assigned to The Steel Company of Canada, Ltd., Hamilton, Ontario). Process for Coating Zinc and Zinc-Iron Alloy Surfaces. U.S. Pat. 3,127,288, Mar. 31. 1964.

[44] Schrader, Carlton F. (assigned to Inland Steel Co., Chicago, Ill.). Soft Ductile, Galvanized Material. U.S. Pat. 3,149,928, Sept. 22, 1964.

Many examples of design and application of zinc-base alloy die castings are included in a survey of the American die casting industry.[45]

A study of an electric cell using an aqueous zinc bromide electrolyte and carbon plate electrodes yielded results verifying the high theoretical energy of the reactants.[46] Zinc oxide crystals up to 100 grams in weight have been grown for testing applicability as a transducer for ultrasonic amplifiers.[47] Patents were granted for treating zinc oxide for photoconductive properties,[48] for production or purification of other zinc containing compounds,[49] and for a method of forming an aqueous solution of zinc sulfate and ammonia for a liquid fertilizer.[50]

Research was conducted on the anodic behavior of zinc anodes in an alkali.[51] A patent was granted on producing a bonded zinc-aluminum extrusion for use as a sacrificial anode.[52]

Basic research developed a number of stress-strain relationships for zinc,[53] strength of zinc oxide agglomerates,[54] and phase studies of iron-zinc alloys.[55]

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[45] Steel. Booming Technology Boon to Diecasting User. V. 155, No. 2, July 13, 1964, pp. 55–70.

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[47] Electronic News. Heavy Zinc Oxide Crystals Reported. V. 9, No. 433, May 18, 1964, p. 39.

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Zirconium and Hafnium

By John G. Parker[1]

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ZIRCON production and sales by domestic mining companies were about 10 percent greater than in 1963, and Australian output probably increased in like manner. Domestic output of zirconium sponge and hafnium oxide decreased significantly, but production of zirconium ingot increased slightly from 1963.

LEGISLATION AND GOVERNMENT PROGRAMS

Disposal of zircon by sales from the strategic stockpile dropped to 232 short tons, about 5 percent of those made during 1963. Final delivery of 26.5 tons of zirconium sponge was made to the U.S. Atomic Energy Commission (AEC) under terms of contracts which had expired during the previous year. In 1964 the AEC also acquired 5 tons of hafnium oxide from domestic producers.

TABLE 1.—Salient zirconium and hafnium statistics in the United States

	1963	1964
Zircon:		
Production, short tons	W	W
Imports, do	52,543	44,413
Exports, do	1,418	2,500
Consumption[1], do	37,500	29,520
Consumers and dealers yearend stocks[1], do	21,673	39,515
Price, per short ton	$47.25	$47.25
Zirconium sponge:		
Production, short tons	1,022	W
Producers stocks, do	216	W
Hafnium oxide:		
Production[2], do	55	W
Producers stocks, do	26	W

W Withheld to avoid disclosing company confidential data.
[1] Excludes foundries.
[2] Metal content of oxide produced.

DOMESTIC PRODUCTION

Florida beach sands, mined primarily for titanium minerals, provided coproduct zircon. Companies processing these sands were: E. I. du Pont de Nemours & Co., Inc., Trail Ridge mine, Starke; Titanium Alloy Manufacturing Division, National Lead Co., Skinner mine, Jacksonville; and The Florida Minerals Co., Vero mine, Vero

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[1] Commodity specialist, Division of Minerals.

Beach. Zircon production increased nearly 10 percent, and sales increased at nearly the same rate.

Because of dwindling reserves, it was announced that mining operations would cease at the Jacksonville titanium-zirconium mineral deposit by May 1965. At a new concentration and separation plant northeast of Folkston, Ga., Humphreys Mining Co., will produce titanium and zirconium concentrates for Du Pont.

Production of zirconium sponge and hafnium oxide by three companies decreased but that of hafnium sponge increased slightly. Figures are withheld to avoid disclosing company confidential data of The Carborundum Metals Co. Division, The Carborundum Co., Parkersburg, W. Va.; Wah Chang Corp., Albany Division, Albany, Oreg.; and Reactive Metals, Inc., Ashtabula, Ohio. The last concern, a successor to U.S. Industrial Chemicals Co., was formerly an inactive corporation which was recapitalized and reorganized in 1964 as an equally-owned venture of United States Steel Corp. and National Distillers & Chemical Corp. Carborundum Metals Co. curtailed sponge production at Parkersburg, W. Va., and Akron, N.Y.

Zirconium ingot production from sponge was continued at the Akron, N.Y., facility and at Wah Chang Corp. Reactive Metals, Inc., also produced ingots, mostly at the former Bridgeport Brass Co. plant at Niles, Ohio, from sponge produced at Ashtabula. The Ashtabula plant also produced chunklets and a small quantity of ingot. The only other company converting sponge to ingot was Harvey Aluminum, Inc., Torrance, Calif. Production of zirconium ingot and chunklets was 1,193 tons.

Zirconium powder produced by Carborundum Metals Co.; Foote Mineral Co., Exton, Pa.; Nuclear Materials & Equipment Corp., Apollo, Pa.; and Wah Chang Corp. totaled nearly 17 tons. Scrap and fines totaling 265 tons was generated by processors and 229 tons was reused.

Producers of zirconium alloys included Metal Hydrides, Inc., Beverly, Mass.; Titanium Alloy Manufacturing Division, National Lead Co., Niagara Falls, N.Y.; Union Carbide Corp., Metals Division, Alloy, W. Va., and Niagara Falls, N.Y.; and Vanadium Corporation of America, Cambridge, Ohio.

Hafnium crystal bar was produced by Foote Mineral Co., and Nuclear Materials & Equipment Corp.

Output of zirconium oxide, excluding that made in metal production, was about 4,800 tons, nearly a 10 percent decrease. Most of this oxide was produced by Titanium Alloy Manufacturing Division, National Lead Co.: Harbison-Carborundum Corp., Falconer, N.Y.; The Norton Co., Huntsville, Ala.; and Zirconium Corporation of America, Solon, Ohio.

Zircon and zirconia-based refractories were processed by 9 concerns at 11 locations. The largest producers of these refractories were Corhart Refractories Co., Louisville, Ky., and Buckhannon, W. Va.; The Chas. Taylor Sons Co., Cincinnati, Ohio, and South Shore, Ky.; Harbison-Carborundum Corp.; Walsh Refractories, St. Louis, Mo.; and A. P. Green Fire Brick Co., Remmey Division, Philadelphia, Pa. Production of zircon- and zirconia-refractories was about 20,300 tons, containing an estimated 9,700 tons of zirconia.

The principal processors of zircon to primary zirconium compounds, consisting mostly of zirconium oxide, were Titanium Alloy Manufacturing Division, Norton Co., and Tizon Chemical Corp., Flemington, N.J.

M & T Chemicals, Inc., opened a highly automated plant at Andrews, S.C., for producing zirconium silicate ceramic opacifiers.

CONSUMPTION AND USES

Zircon was used mostly in foundry sands and, although consumption data are not available, it is probable that well over one-half of the zircon was consumed by foundries. Other consumption consisted of about 23,680 tons for refractory, chemical, ceramic, and abrasive production. Consumption for sponge, ingot, and alloy production totaled about 5,840 tons, a substantial drop from the previous year when four concerns were producing zirconium sponge.

Because of transparency to neutrons and resistance to high-temperature water corrosion, zirconium alloys with low-hafnium content were used as cladding for nuclear fuel elements, chiefly in naval propulsion and experimental reactors. They were used also in some boiling water and heavy water power reactors.

High-purity hafnium, because of its high thermal neutron cross section, was used as an absorber material in some power reactor control rods. Zirconium and hafnium are used in new columbium-, tantalum-, and molybdenum-base alloys suitable for high-temperature and aerospace applications. A new 32,800-gauss, superconducting-magnet system, having a center bore containing columbium and zirconium, is a part of the new Zero Gradient Synchotron, which was being built to study subnuclear particles.

Zirconium hydride is used in experimental and teaching reactors and in the SNAP (Systems for Nuclear Auxiliary Power) program because of its excellent properties as a neutron moderator. Coatings of zirconium compounds, such as the diboride, provide corrosion and oxidation resistance for high-temperature strength materials used for process equipment.

Zircon molding sands with excellent casting qualities have a higher melting point and lower thermal expansion than those containing silica and olivine. Zircon was used in corrugated ceramics, a new lightweight development in heat exchangers and thermal insulators, with resistance to high temperature, thermal shock, and corrosion. Zircon was used as bonded refractories in aluminum- and glass-melting furnaces and was fused with other materials such as bauxite or chromite to form electrocast refractories with low porosity and high abrasion resistance. In the ceramic industry, electrical porcelain containing zircon is second only to certain high-alumina materials; some glazes are opacified by zircon.

Other new applications include development of a technique for improving the resistance of cotton to rot and weather by treating with zirconium-copper and zirconium-mercury compounds, and production of a washable, self-polishing floor wax with a zirconium compound component.

Minor uses are for tanning certain types of leather, for a body deodorant, for a superior lighting agent in photographic flash bulbs, and for a component of petroleum-cracking compounds.

STOCKS

Dealer stocks of zircon concentrate were 12,758 tons at the end of 1964, and consumer stocks, excluding those of foundries, increased more than 60 percent to 26,817 tons. Stocks of zirconium oxide held by consumers at yearend, excluding zirconia content of refractories, totaled nearly 2,000 tons.

Zircon concentrate in the strategic stockpile at yearend totaled 1,920 tons; that of baddelleyite, 16,533 tons. As of June 30, 1964, the AEC had an inventory of 2,640 tons of equivalent zirconium sponge and 45 tons of equivalent hafnium crystal bar.

PRICES

Quotations from various sources for zircon concentrate, zirconia, zirconium, and hafnium were as follows:

		Price
Zircon:		
Domestic, containing 66 percent ZrO_2, f.o.b. Starke, Fla., per short ton [1]		$47.25
Domestic, granular, 1- to 5-ton lots, from works, per pound in bags [2]		.03625
Imported, containing 65 percent ZrO_2, c.i.f.:		
Atlantic Ports, per long ton [1]		50.00
After Sept. 1, 1964		61.00
Zirconium oxide: [2]		
Various purities and physical forms, in lot sizes to carloads, per pound, usually in bags		.33 to 1.50
Zirconium: [3]		
Flash grade powder	per pound	10.00
Sponge	do	4.25 to 5.00
Sheets, strip, and bars	do	10.00 to 14.00
Hafnium: [3]		
Sponge	do	75.00
Rolled bar and plate	do	138.00

[1] E&MJ Metal and Mineral Markets. V. 35, Nos. 1-52, January-December 1964.

[2] Oil, Paint and Drug Reporter. V. 185, Nos. 1-26, Jan. 6-June 29, 1964; v. 186, Nos. 1-26, July 6-Dec. 28, 1964.

[3] American Metal Market. V. 71, Nos. 1-252, January-December 1964.

There was an increase of nearly 5 percent in unit value of domestic zircon sold in 1964.

FOREIGN TRADE

Imports.—Imports for consumption of zircon concentrates decreased more than 15 percent from the previous year. Under tariff classification 629.600, 4,900 pounds of unwrought zirconium metal worth $37,084 was imported from West Germany; 49,026 pounds of metal, probably consisting in part of waste and scrap and valued at $19,774, was received from Canada, United Kingdom, and Australia. Unwrought zirconium alloys totaling 2,372 pounds, valued at $14,913, were imported from West Germany and Belgium-Luxembourg;

wrougth zirconium totaling 326 pounds worth $3,145 was shipped from Canada, France, and West Germany. Imports of another alloy, ferrozirconium, from France, totaling 55,116 pounds were valued at $10,713. The oxide, mostly from Canada and also from the United Kingdom with very small quantities from West Germany and Switzerland, totaled 229,961 pounds, valued at $37,114. Imports of other zirconium compounds, from Japan, United Kingdom, Canada, West Germany, and Netherlands, in order of quantity, totaled 1,238,785 pounds worth $158,299. Unit values for most of the oxide and compounds ranged from 9 to 59 cents. Unwrought hafnium metal, including waste and scrap and totaling 7 pounds valued at $336, was imported from West Germany.

TABLE 2.—U.S. imports for consumption of zircon, by countries

(Short tons)

Country	1955–59 (average)	1960	1961	1962	1963	1964
Argentina	-----	-----	-----	-----	-----	40
Australia	34,475	29,183	31,225	27,001	50,004	42,903
Austria	-----	-----	-----	-----	11	-----
Brazil [1]	376	-----	4	-----	-----	-----
Canada [2]	68	2	-----	1	24	848
Nigeria	184	1,850	-----	544	981	622
South Africa, Republic of	56	3,133	2,576	3,326	1,523	-----
United Kingdom [2]	46	112	-----	-----	-----	-----
Total: Quantity	35,205	34,280	33,805	30,872	52,543	44,413
Value	$946,482	$1,233,815	$873,376	$844,939	1,715,878	$1,184,021

[1] Concentrate from Brazil includes some baddeleyite.
[2] Believed to be country of shipment rather than country of origin.

Source: Bureau of the Census.

Exports.—Zircon ores and concentrates totaling 2,500 tons, valued at $352,345, were exported to 15 countries. Almost two-thirds of this material, having slightly more than one-half the total value, was shipped to Canada. Exports of zirconium metal and alloys in crude form and scrap, totaling 467,479 pounds valued at $2,104,499, were made to 7 countries; almost three-quarters of these materials by quantity and value was shipped to the United Kingdom. Semifabricated zirconium and zirconium alloys, totaling 65,970 pounds valued at $1,086,934, were exported to 14 countries. Of these exports, more than 35 percent worth more than $400,000 was shipped to Canada, 30 percent valued at $200,000 was sent to the United Kingdom, and more than 15 percent worth almost $250,000 was shipped to Switzerland.

WORLD REVIEW

Australia.—In New South Wales, zircon was produced at Cudgen by N. S. W. Rutile Mining Co., Pty., Ltd.; Titanium Alloy Manufacturing Co., Associated Minerals Consolidated, Ltd.; and Cudgen RZ Pty.; at Newcastle by Wyong Minerals Ltd., and by Rutile & Zircon Mines (Newcastle), Ltd.; at Byron Bay by Zircon Rutile Byron Bay Pty., Ltd.; and at Port Macquarie by Mineral Deposits Pty., Ltd. In

Queensland it was produced at Southport by Mineral Deposits Pty., Ltd. and at Stradbroke Island by Titanium & Zirconium Industries Pty., Ltd.[2]

TABLE 3.—Free world production of zirconium concentrates by countries [1]

(Short tons)

Country	1955–59 (average)	1960	1961	1962	1963	1964
Australia	85,638	114,645	152,836	149,904	205,970	207,650
Brazil [2]	5,858	6,358	7,405	2,642	392	NA
India	8	[e] 10	[e] 10	NA	NA	NA
Malagasy Republic	15	375	353	390	428	NA
Malaysia	[3] 69	63	[4] 63	[4] 67	227	[4] 200
Nigeria	[5] 676	1,968	833	[6] 545	886	[6] 622
Senegal	4,511	11,408	5,939	2,575	3,383	NA
South Africa, Republic of	[5] 3,526	7,366	7,607	7,581	2,648	NA
United Arab Republic (Egypt)	137	408	105	188	44	NA
United States	[7] 39,883	W	W	W	W	W

[e] Estimate. NA Not available. W Withheld to avoid disclosing individual company confidential data.
[1] Table incorporates revisions.
[2] Chiefly baddeleyite.
[3] Average annual production 1956–59.
[4] Exports.
[5] Average annual production 1958–59.
[6] U.S. imports.
[7] Average annual production 1955–58.

Associated Minerals Consolidated Ltd., Sydney, announced that during fiscal year 1964, 61,740 tons of zircon products was produced. Sales totaled 68,330 tons of zircon, an increase of 40 percent from the previous year.[3] Another producer, Rutile & Zircon Mines (Newcastle), Ltd., increased rate of zircon output by more than 40 percent from the first to third quarter of 1964.[4]

Brazil.—Export under quota of 600 tons of zircon concentrate, including baddeleyite and caldasite, was permitted by the National Atomic Energy Commission during the first half of 1964. It was reported the quotas would depend on the beneficiation state of the ore, the immediately deliverable quantities, the ore reserve status of the mining company, and its history as an exporter of such ores or concentrates.[5]

Canada.—Eldorado Mining & Refining, Ltd., announced pilot-plant stage development of a fluoridation technique for refining zirconium circumventing the conventional chlorination technology, which requires a sponge metal stage.[6]

India.—The Indian Atomic Energy Commission produced high-purity zirconium metal from Indian zircon at a newly opened pilot plant at Trombay. The metal was required for a nuclear installation planned for Rajasthan.[7]

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[2] Mining Engineering. Rutile-Zircon Mining on East Coast Surfing Beaches. V. 16, No. 10, October 1964, pp. 109–110.
[3] Associated Minerals Consolidated, Ltd. (Sydney, Australia). Twelfth Annual Report and Balance Sheet for 1964. 15 pp.
[4] Canadian Mining Journal (Gardenvale, Quebec, Canada). V. 85, No. 12, December 1964, p. 89.
[5] Mining Journal (London). V. 262, No. 6714, Apr. 24, 1964, p. 323.
[6] Chemical Week. V. 95, No. 13, Sept. 26, 1964, p. 64.
[7] Metal Bulletin (London). No. 4922, Aug. 18, 1964, p. 17.

TECHNOLOGY

The Bureau of Mines research program for zirconium and hafnium included studies about bacterial separation of metal values from ores and industrial waste products; improving fractional crystallization techniques and using halogenation methods to separate hafnium from zirconium; electrowinning hafnium metal from its tetrachloride; developing fabrication techniques for and testing mechanical properties and corrosion resistance of certain zirconium-bearing alloys; preparing zirconia-metal mixtures for powder metallurgy compacts with high-temperature properties; evaluating hafnium carbide castings; synthesizing zirconium compound asbestiform fibers; analyzing phase equilibria in zirconia systems; forming zirconia shapes; joining dissimilar zirconia and other zirconium compound refractories; and determining the feasibility of using zirconia electrolytes in fuel cells.

Important thermodynamic data were obtained;[8] vapor pressure measurements made on hafnium iodide differed considerably from those made by earlier investigators;[9] hafnium purification by electronbeam melting was described;[10] a new expendable graphite mold material was devised which was useful in casting zirconium and hafnium and suitable for adaptation to standard foundry techniques;[11] and an improved optical spectrographic technique was used to analyze for traces of impurities in high-purity hafnium.[12] Phase equilibria studies were conducted on various alloy systems containing zirconium and hafnium, and refractory base metals allowed with these elements were investigated for use as high-temperature structural materials.[13] Corrosion behavior and mechanical properties of a standard zirconium alloy were studied,[14] and the harshness of zirconium diboride was increased by adding certain metallic binders, the best of which was chromium.[15]

The AEC continued sponsoring metallurgy research, much of it at national laboratories, on corrosion-resistant zirconium alloys and including improvement of fabricating techniques. Some investigations were conducted on hafnium and hafnium systems.

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[8] Mah, Alla D. Heats of Formation of Zirconium Carbide and Hafnium Carbide. BuMines Rept. of Inv. 6518, 1964, 8 pp.

[9] Stevenson, F. D., C. E. Wicks, and F. E. Block. Vapor Pressure of Tungsten (VI) Chloride and Hafnium (IV) Iodide by a Metal Diaphragm Technique. BuMines Rept. of Inv. 6367, 1964, 32 pp.

[10] Anable, W. E., and R. A. Beall. Electron-Beam Purification of Hafnium. BuMines Rept. of Inv. 6560, 1964, 30 pp.

Wood, F. W., J. L. Hoffman, W. E. Anable, and R. A. Beall. A System for Electron-Beam Melting. BuMines Rept. of Inv. 6341, 1964, 35 pp.

[11] Ausmus, S. L., and R. A. Beall. Expendable Casting Molds for Reactive Metals. BuMines Rept. of Inv. 6509, 1964, 44 pp.

[12] Carpenter, Lloyd, and Richard W. Lewis. Analysis of High-Purity Hafnium by Optical Emission Spectrography. BuMines Rept. of Inv. 6384, 1964, 16 pp.

[13] Babitzke, H. R., M. D. Carver, and H. Kato. Columbium and Tantalum Alloys Suitable for Use at High Temperature. BuMines Rept. of Inv. 6390, 1964, 25 pp.

Babitzke, H. R., R. E. Siemens, G. Asai, and H. Kato. Development of Columbium and Tantalum Alloys for Elevated-Temperature Service. BuMines Rept. of Inv. 6558, 1964, 33 pp.

Crosby, R. L., and L. W. Higley, Jr. Intermetallic Phases in Magnesium-Rich Magnesium-Aluminum-Zirconium Alloys. BuMines Rept. of Inv. 6498, 1964, 13 pp.

Oden, Laurance L., D. K. Deardorff, M. I. Copeland, and H. Kato. The Hafnium-Tantalum Equilibrium Diagram. BuMines Rept. of Inv. 6521, 1964, 12 pp.

Siemens, R. E., H. R. Babitzke, and H. Kato. Columbium-Hafnium Equilibrium Diagram. BuMines Rept. of Inv. 6492, 1964, 11 pp.

[14] Kato, H., D. J. Stoops, and M. D. Carver. Effect of Impurity Levels on Zircaloy 2 Microstructure, Mechanical Properties, and Corrosion Rates. BuMines Rept. of Inv. 6536, 1964, 20 pp.

[15] Tyrrell, M. E., and C. W. Houck. Metallic Binders for Zirconium Diboride: Chromium, Molybdenum, and Tungsten. BuMines Rept. of Inv. 6549, 1964, 14 pp.

A beneficiation process was patented for separating aluminum silicates and zircon from heavy beach sand mineral concentrates.[16] As a preliminary step in extracting zirconium, zircon sand was fritted with sodium hydroxide in a 1 to 1.4 ratio—the reaction starting at about 550° C, and the optimum conversion temperature being 100° C higher.[17] The products were mostly acid-soluble sodium zirconate and lesser sodium silicate and unreacted zircon.

Mechanics of the reaction involved when crystal-bar zirconium is dissolved in aqueous solutions of acid were studied,[18] and the high-temperature oxidation of zirconium and its alloys was investigated.[19] Oxide films formed by high-temperature water and steam corrosion and corrosion of zirconium and some zirconium alloys in alkaline solutions were studied.[20]

Phase equilibria studies were conducted on zirconium and hafnium alloy systems.[21] In certain zirconium-columbium alloys the quantity of alpha zirconium increased when oxygen was added and it was independent of temperature in the range studied. The binary columbium-hafnium system resembles the columbium-titanium and columbium-zirconium systems in having two single-phase fields; one is a close-packed α-Hf phase existing below 1,950° C.

After a homogenized magnesium-0.6-percent zirconium alloy was heated in hydrogen, directional diffusion prevailed over slip creep as the dominant deformation mode at sufficiently low stresses.[22] This is due to the preferential formation of ϵ-zirconium-hydride particles at grain boundaries and at dislocations.

Zirconia samples were mounted at high pressure in glass-filled dially phthalate powders.[23] Grinding, polishing, and etching with boiling phosphoric acid were necessary to prepare the finished mounts for microscopic examination. Research conducted on zirconium oxide systems indicated that adsorption of molecular ozygen by powdered ZrO_2 is primarily a surface phenomenon related to electron transfer and that the molecular oxygen then dissociates and is adsorbed as atoms.[24] Studies of the electrical properties of ZrO_2-CaO solid solutions indicated that electrical conductivity decreases from the single-phase cubic solid solution toward the two adjacent two-phase regions, most rapidly toward that rich in ZrO_2.[25] Research was conducted on refractory carbides of zirconium and hafnium.[26] Ternary compounds were prepared and examined. Tension and creep properties of zirconium carbide showed weakening of structure more than 2,100° C, which was probably due to impurities at grain boundaries; thermal expansion measurements to 2,843° C showed evidence for a high-temperature inversion in zirconium monocarbide. Other investigations on high-temperature ceramic materials included measurements on the expansion of hafnium oxide, stabilized hafnium oxide, and thorium oxide.[27] Strontium zirconate, another refractory ceramic material with a melting point of 5,160° F (2,850° C) and resistance to stress, was investigated for possible use for radomes on supersonic aircraft and rocket nozzles.[28] Air Force researchers decomposed zirconium and hafnium isopropoxides to vapor phases and then deposited them on graphite to form thin oxidation-resistant films of zirconia and hafnia.[29]

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[16] Baarson, Robert E., and Charles W. Jonaitis (assigned to Armour & Co., Chicago, Ill.). Flotation Process to Produce Separate Aluminum Silicates and Zircon Concentrates From a Heavy Mineral Beach Sand Concentrate. U.S. Pat. 3,117,924, Jan. 14, 1964.

[17] Choi, Hyung Sup, and H. Cross. Study of the Fritting Reaction of Zircon Sand With Sodium Hydroxide Using Differential Thermal Analysis and X-Ray Techniques. Canadian Min. and Met. Bull. (Montreal, Canada), v. 57, No. 629, September 1964, pp. 966–972.

[18] Meyer, Robert E. The Electrochemistry of the Dissolution of Zirconium in Aqueous Solutions of Hydrofluoric Acid. J. Electrochem. Soc., v. 111, No. 2, February 1964, pp. 147–155.

[19] Hussey, R. J., and W. W. Smeltzer. The Mechanism of Oxidation of Zirconium in the Temperature Range 400°–850° C. J. Electrochem. Soc., v. 111, No. 11, November 1964, pp. 1221–1224.

Westerman, R. E. High-Temperature Oxidation of Zirconium and Zircaloy-2 in Oxygen and Water Vapor. J. Electrochem. Soc., v. 111, No. 2, February 1964, pp. 140–147.

[20] Douglass, D. L., and H. A. Fisch. The Effect of Heat-Treatment on the Corrosion and Hydrogen Pickup Behavior of a Zr-Sn-Nb Alloy in High Temperature Water and Steam. J. Electrochem. Soc., v. 111, No. 7, July 1964, pp. 787–795.

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[21] Marcotte, V. C., W. L. Larsen, and D. E. Williams. Phase Relationships of the Oxygen-Containing 20 and 25 Percent Zirconium-Niobium Alloys. J. Less-common Metals (Amsterdam, Netherlands), v. 7, No. 5, November 1964, pp. 373–382.

Taylor, A., and N. J. Doyle. The Constitution Diagram of the Niobium-Hafnium System. J. Less-Common Metals (Amsterdam, Netherlands), v. 7, No. 1, July 1964, pp. 37–53.

[22] Harris, J. E., and P. G. Partridge. Zirconium-Hydride Formation in Homogenized Magnesium-Zirconium Alloy. J. Inst. Metals (London), v. 93, pt. 1, September 1964, pp. 15–18.

[23] Slepian, R. M. Preparation of Stabilized Zirconia for Microscopic Examination. J. Am. Ceram. Soc., v. 47, No. 10, Oct. 21, 1964, pp. 535, 536.

Patents were issued resulting from research by major oil companies on zirconium-bearing catalysts.[30]

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[24] Smith, Tennyson. Zirconium Dioxide-Oxygen Reactions. I. Molecular Oxygen Adsorption With Electron Transfer. J. Electrochem. Soc., v. 111, No. 9, September 1964, pp. 1020–1027; II. Chemisorption of Atomic Oxygen. pp. 1027–1031.

[25] Tien, T. Y. Electrical Conductivity in the System ZrO_2–$CaZrO_3$. J. Am. Ceram. Soc., v. 47, No. 9, Sept. 21, 1964, pp. 430–433.

[26] Jeitschko, W., H. Nowotny, and F. Benesovsky. Carbides of Formula T_2MC. J. Less-Common Metals (Amsterdam, Netherlands), v. 7, No. 2, August 1964, pp. 133–138.

Leipold, Martin H., and Thomas H. Nielson. Mechanical Properties of Hot-Pressed Zirconium Carbide Tested to 2,600° C. J. Am. Ceram. Soc., v. 47, No. 9, Sept. 21, 1964, pp. 419–424.

Miccioli, Bruno R., and Peter T. B. Shaffer. High-Temperature Thermal Expansion Behavior of Refractory Materials: I, Selected Monocarbides and Binary Carbides. J. Am. Ceram. Soc., v. 47, No. 7, July 1964, pp. 351–356.

[27] Ohnysty, Basil, and F. K. Rose. Thermal Expansion Measurements on Thoria and Hafnia to 4,500° F. J. Am. Ceram. Soc., v. 47, No. 8, August 1964, pp. 398–400.

[28] Ceramic Age. V. 80, No. 11, November 1964, pp. 52–53.

[29] Chemical Week. V. 95, No. 26, Dec. 26, 1964, p. 42.

[30] Cramer, Robert H., and Sylvander C. Eastwood (assigned to Socony Mobil Oil Co., Inc.). Manufacture of Silica-Zirconia-Alumina Catalyst. U.S. Pat. 3,140,250, July 7, 1964

Drake, Leonard C., Charles J. Plank, Edward J. Rosinski, and Robert B. Smith (assigned to Socony Mobil Oil Co., Inc.). Preparation of a Silica-Zirconia Catalyst for Conversion of Hydrocarbons. U.S. Pat. 3,137,658, June 16, 1964.

Dwyer, Francis G., and Sylvander C. Eastwood (assigned to Socony Mobil Oil Co., Inc.). Zirconium-Aluminum-Phosphorus Catalyst and Method for Preparing the Same, Employed for the Cracking of Hydrocarbons. U.S. Pat. 3,130,147, Apr. 21, 1964.

Hansford, Rowland C. (assigned to Union Oil Company of California). Coprecipitated Alumina-Zirconium Oxide Sulfate-Containing Catalyst. U.S. Pat. 3,132,110, May 5, 1964.

Hansford, Rowland C., and Dean Arthur Young (assigned to Union Oil Company of California). Composite Silica-Zirconia Hydrocracking Catalyst and Process. U.S. Pat. 3,120,483, Feb. 4, 1964.

Thomas, Charles L. (assigned to Sun Oil Co.). Gamma Alumina Supported Titanium and Zirconium Subhalides Polymerization Catalysts and Preparation Thereof. U.S. Pat. 3,153,634, Oct. 20, 1964.

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ARSENIC [1]

DOMESTIC OUTPUT of white arsenic, As_2O_3, was derived entirely as a byproduct of smelting arsenic-containing copper ores by The Anaconda Company at Anaconda, Mont., and American Smelting and Refining Company at Tacoma, Wash. Arsenic metal was not produced.

Consumption and Uses.—Most of the white arsenic produced in 1964 was consumed in manufacturing lead and calcium arsenate insecticides. In the 12 year period since 1951 the production of lead arsenate insecticide has varied between 7,800 tons and 4,900 tons, indicating that lead arsenate has maintained its position in competition with organic insecticides.

Arsenic compounds also were used in weedkillers, glass manufacture, cattle and sheepdips, dyestuffs, and wood preservatives. Minute quantities of arsenic compounds were used in masers and lasers. Apparent consumption of white arsenic increased 8 percent from 1963.

The Food and Drug Administration declared that the use of orthoarsenic acid is safe as a defoliant in the production of cotton so long as any residue does not exceed 4 parts per million expressed as As_2O_3 in the raw cottonseed.[2]

Stocks.—Stocks of white arsenic declined 68 percent while shipments increased 23 percent, and total new supply (production and imports for consumption) was about 2,100 tons more than in 1963.

Prices.—The price of white arsenic was increased by $6 per short ton on April 1 by the American Smelting and Refining Company.[3]

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[1] Prepared by Arnold M. Lansche.

[2] Oil, Paint and Drug Reporter. V. 186, No. 5, Aug. 3, 1964, p. 25.

[3] American Metal Market. V. 71, No. 57, Mar. 23, 1964, p. 13.

TABLE 1.—Consumption of arsenic wood preservatives in the United States
(Short tons)

Year	Consumption of wood preservatives	
	Wolman salts (25 percent sodium arsenate)	Other
1962	1,358	1,758
1963	1,721	1,392
1964	[p] 1,847	[p] 1,562

[p] Preliminary.

Source: Forest Service, U.S. Department of Agriculture.

The increase applied to bulk, barrels, and drums of crude white arsenic. Shipments from Tacoma, Wash., and Laredo, Tex., to the east coast of the United States in barreled carlots were delivered at $109.64 per ton (5.4 cents per pound) for crude, and $127.64 per ton (6.4 cents per pound) for refined white arsenic. Bulk carload prices were $77.64 per ton for crude, and $95.64 per ton for refined. These prices were maintained for the remainder of the year. The price of lead arsenate packed in 3- to 50-pound bags opened the year at 26 cents per pound; on March 30 the quotation was 27 cents, at which it remained through December 31. Lead arsenate in 1-pound bags was quoted at 36 cents per pound during 1964.

The price of refined white arsenic in 1960 was 4 to 5 cents per pound, in 1961 and 1962 it had been 4 cents, and beginning with 1963 it was quoted at 5.1 cents per pound, f.o.b., Laredo, Tex.

The London price, quoted from the Metal Bulletin, for white arsenic in 1964 was £40 to £45 per long ton (5.00 to 5.63 cents per pound) for 98 percent minimum purity. Arsenic metal on the London market was quoted at £400 per long ton or 50 cents a pound.

Foreign Trade.—Nearly all of 154 tons of arsenic metal imported came from Sweden; Poland and Danzig together provided about 6 tons; Canada and West Germany supplied 187 pounds and 2 pounds respectively. Sweden and France supplied 500 tons and 15 tons, respectively, of arsenic acid; Canada and West Germany supplied 800 pounds and about 2 tons, respectively, of lead arsenate; the United Kingdom provided 161 tons of sodium arsenate; about 10 tons of sheepdip was bought from Australia; and 4 pounds of other arsenic compounds came from Canada.

No exports of white arsenic were reported. The calcium arsenate exported totaled 769 tons valued at $96,374; Chile received 2 tons, Colombia 352 tons, Costa Rica 25 tons, El Salvador 110 tons, Guatemala 224 tons, Israel 45 tons, Japan 7 tons, Peru 2 tons, and Trinidad and Tobago 2 tons.

Exports of lead arsenate totaled 936 tons valued at $278,058; the Bahama Islands received about 2 tons, Canada 26 tons, Chile 3 tons, Colombia 760 tons, Costa Rica 46 tons, Greece 11 tons, Guatemala 47 tons, Mexico 2 tons, Nicaragua 14 tons, Panama 2 tons, and Peru 23 tons; Bermuda received about 500 pounds.

TABLE 2.—U.S. imports for consumption of white arsenic (As_2O_3 content), by countries

Country	1962		1963		1964	
	Short tons	Value	Short tons	Value	Short tons	Value
North America:						
Canada	-----	-----	2	$264	35	$4,486
Mexico	10,935	$799,097	10,641	811,643	11,860	937,986
Total	10,935	799,097	10,643	811,907	11,895	942,472
Europe:						
France	4,003	226,975	2,116	130,781	3,430	231,022
Sweden	804	49,666	1,800	115,767	2,847	208,804
Other countries [1]	16	783	-----	-----	13	1,080
Total	4,823	277,424	3,916	246,548	6,290	440,906
Grand total	15,758	1,076,521	14,559	1,058,455	18,185	1,383,378

[1] Includes Netherlands, Portugal, and U.S.S.R.

Source: Bureau of the Census.

TABLE 3.—U.S. imports and exports of arsenicals, by classes

(Pounds)

Class	1962	1963	1964
Imports for consumption:			
White arsenic (As_2O_3 content)	31,515,599	29,117,679	36,370,155
Metallic arsenic	229,439	[r] 337,582	307,885
Sulfide	66,160	35,824	55,116
Sheepdip	14,765	19,656	19,686
Calcium arsenate	-----	-----	-----
Sodium arsenate	255,466	272,946	321,290
Exports:			
Calcium arsenate	942,399	186,577	1,537,484
Lead arsenate	1,422,795	802,664	1,871,803

[r] Revised.

Source: Bureau of the Census.

World Review.—*Belgium.*—Société Generale Metallurgique de Hoboken produced 99.999 percent pure amorphous arsenic metal; impurity content was reported to be less than 1 part per million copper and iron, less than 0.3 part per million silicon and magnesium and less than 3 parts per million sulfur.

Japan.—The Mitsubishi Metal Mining Co., which began producing 99.9999 percent pure arsenic metal in 1963, exported 1,000 grams to the United Kingdom in 1964 at a price of 40 cents per gram c.i.f.

South-West Africa.—New smelters of the Tsumeb Corp., Ltd., were reported capable of 4,000 tons per year output of white arsenic.[4]

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[4] Engineering and Mining Journal. V. 165, No. 4, April 1964, p. 192.

TABLE 4.—Free world production of white arsenic, by countries [1] [2]

(Short tons)

Country	1962	1963	1964
Brazil	164	323	[e] 300
Canada	80	94	150
France	7,477	[3] 10,540	[e] 12,000
Germany, West (exports)	75	62	[e] 44
Italy	140	---	---
Japan	1,011	904	[4] 904
Mexico	[5] 12,000	[5] 10,779	[5] [e] 14,000
Peru	572	683	[e] 700
Portugal	634	622	[6] 4,200
Southern Rhodesia	1,207	605	206
Spain	234	163	126
Sweden	6,342	[e] 12,100	[e] 12,100
Total [7] [e]	45,200	51,700	58,000

[e] Estimate.

[1] Arsenic may be produced in Argentina, Austria, China, Czechoslovakia, East Germany, Finland, Hungary, U.S.S.R., and the United Kingdom, but there is too little information to estimate production.

[2] This table incorporates some revisions. Data do not add exactly to totals shown because of rounding where estimated figures are included in the detail.

[3] Exports.

[4] 1963 data.

[5] Including black arsenic.

[6] Estimated equivalent recoverable arsenic trioxide content of concentrates produced.

[7] United States data included in world total.

CESIUM AND RUBIDIUM [5]

In contrast to 1963, outputs of cesium metal and compounds decreased sharply in 1964.

Domestic Production.—Three firms processed pollucite to cesium primary products. They were Penn Rare Metals, Division of Kawecki Chemical Co., Revere, Pa., and The Dow Chemical Co., Midland, Mich., which produced cesium metal and cesium compounds; and Rare Metals Derivatives, Inc., Ambler, Pa., which produced cesium compounds. Penn Rare Metals also processed rubidium-bearing raw material to rubidium metal and compounds. Outputs of cesium metal, cesium compounds, and rubidium compounds were much smaller in 1964 than in 1963. Some rubidium metal was produced in 1964. Data on outputs are withheld to avoid disclosing company confidential information.

Consumption and Uses.—Overall pollucite consumption was much smaller in 1964 than in 1963. Consumption data on cesium and rubidium primary products were not available for publication.

Studies on using cesium for high-velocity propellant for rocketry and for the generation of electrical energy continued to expand and to attract wider attention. Various forms of cesium had applications such as in photomultiplier tubes, infrared lamps, scintillation counters, spectrophotometers, and the extremely accurate atomic clock. In some uses, rubidium and some of its compounds can be used as alternatives for cesium and its compounds.

Prices.—American Metal Market quoted the price of cesium, 99+ percent, at $100 to $375 per pound, and rubidium, 99+ percent at $390 to $425 per pound.

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[5] Prepared by Donald E. Eilertsen.

Foreign Trade.—Import figures on cesium metal were not reported separately from various other commodities and were not available. General imports of cesium chloride were 74 pounds, valued at $3,184, from West Germany, and 32 pounds, valued at $2,618, from the United Kingdom. Imports of other cesium compounds were 1,335 pounds, valued at $51,968, from West Germany, and 580 pounds valued at $7,853, from the United Kingdom. No rubidium was imported.

Data on exports of cesium and rubidium metals and their compounds were not available for publication.

Technology.—The Bureau of Mines studied the extraction of cesium and rubidium compounds from pollucite and the recovery of various metals including rubidium from Great Salt Lake brine. Small-scale leaching tests were made on pollucite ore and flotation concentrate products containing more than 20 percent cesium. A hydrochloric acid method extracted more than 97 percent cesium, a sulfuric acid process extracted more than 93 percent cesium, and a chloridizing roast and water procedure extracted more than 96 percent cesium.[6]

The National Aeronautics and Space Administration (NASA), interested in cesium for possible space applications as heat transfer medium and as working fluid in ion propulsion devices, made various studies on the properties of cesium liquid or vapor such as measuring the enthalpy and specific heat from 0° to 1,150° C, heat of fusion, thermal conductivity from 50° to 1,150° C, electrical resistivity at 100° and 1,100° C., and viscosity from 30° to 1,150° C. Studies were underway on the chemical compatibility of cesium with various alloys of copper, iron, molybdenum, nickel, tantalum, titanium, and tungsten. Capsule tests were made at 35° to 1,370° C in cesium liquid or vapor.

NASA development continued on space flight cesium-filled thermionic power converters. A 6,000 hour continuous run at 1,800° C emitter temperature was recorded with a diode consisting of a vapor-deposited tungsten emitter, columbium collector, and alumina seal, the ultimate objective being reliable operation in excess of 10,000 hours. Preliminary studies were made on other types of cesium-containing nonrotating space power generators.

Cesium ion thrust engines of high efficiency are also desirable for space voyages, the engines requiring long-time operation, but not high thrust. NASA ground-tested experimental models for periods close to 1,000 hours and in July 1964 reported the first successful flight test of a 1 KW, 5 millipound thrust engine. Anticipated difficulties with beam neutralization did not materialize during an approximate 1 hour flight.

The U.S. Atomic Energy Commission (AEC) sponsored research on cesium and rubidium, largely on containment alloy and thermodynamic properties for use in the design of nuclear reactors and direct-energy conversion equipment for application in advanced nuclear-electric space powerplants. Columbium containing 1 percent zirconium was found to be corrosion resistant and satisfactory in capsule and boiling dynamic loop experiments up to 1,850° F. The latent heat, vapor pressure, enthalpy, specific heat, and density of the saturated liquid were determined experimentally up to 1,800° F. Heat transfer data in a pumped dynamic boiling loop were also determined for both fluids up to 1,800° F.

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[6] Dean, K. C., P. H. Johnson, and I. L. Nichols. Dissolution and Roasting Techniques for Extracting Cesium from Pollucite Ores. BuMines Rept. of Inv. 6387, 1964, 20 pp.

The acid leaching, basic fusion, and direct reduction methods of extracting cesium from pollucite, the cesium extraction method of The Dow Chemical Co., and information on purifying cesium and analyzing high-purity cesium were described.[7]

The construction and operation of an electrolytic cell for converting high-purity cesium chloride to cesium hydroxide were reported.[8]

The plastic deformation behaviors of single crystal and polycrystalline cesium bromide were studied.[9]

Patents were issued on methods to produce high-purity cesium and cesium compounds from pollucite,[10] to prepare cesium tetrafluorochlorate and rubidium tetrafluorochlorate,[11] to convert cesium alum to radiation source material,[12] and to contain radioactive cesium.[13]

GALLIUM[14]

Output and shipments of domestically produced gallium metal were substantially lower in 1964 than in 1963.

Domestic Production.—Gallium metal was produced by Aluminum Company of America, Bauxite, Ark., and by The Eagle-Picher Co. at its Quapaw and Miami plants near Quapaw, Okla. The Eagle-Picher Co. also produced gallium sesquioxide, gallium trichloride, gallium arsenide, and gallium-indium-tin alloy. Production data are company confidential.

Consumption and Uses.—Figures on the consumption of gallium metal, alloys, and compounds were not available.

Besides gallium's customary uses, such as in selenium rectifiers, in backing for mirrors, in sealant for glass joints in laboratory equipment, and in mass spectrometers, various forms of gallium were used quite extensively in research and development, especially in studies on semiconductors. No new large uses for gallium were reported in 1964, but applications requiring small amounts of gallium continued to emerge from the research and development of recent years.

The short-lived gallium radioisotope 68 was used with the position camera for brain tumor localization.

Solid gallium was found to be useful as lubricant for bearings made of tantalum, zirconium, tungsten, carbon, ceramics, and certain steels in low-temperatures and high-vacuum environment.[15] A trend for larger use of gallium arsenide and gallium phosphide for conversion of electrical energy into light energy was reported.[16] A device using a gallium arsenide radiating diode was constructed for determining the presence and density of fog. An experimental gallium arsenide device was developed that can amplify laser signals more than 1,000 times their original strength; the almost noisefree amplifier can replace photomultiplier tubes in laser experiments. A new gallium arsenide laser was available for uses such as ranging, navigation, and optical radar scanning. Plans were being made to compare the performance of four different solar cell materials, one of which was gallium arsenide, in orbit for approximately 30 days in 1965.

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[7] Moolenaar, R. J. Cesium Metal—Its Production and Purification. J. Metals, v. 16, No. 1, January 1964, pp. 21–24.

[8] Simons, E. L., E. J. Cairns, and L. D. Sangermano. An Electrolysis Cell for the Laboratory-Scale Preparation of Aqueous Cesium Hydroxide Solutions. Electrochem. Technol., v. 2, Nos. 11–12, November–December 1964, pp. 355–356.

[9] Johnson, Lawrence D., and Joseph A. Pask. Mechanical Behavior of Single-Crystal and Polycrystalline Cesium Bromide. J. Amer. Chem. Soc., v. 47, No. 9, September 1964, pp. 437–444.

[10] Moolenaar, Robert J. (assigned to The Dow Chemical Co., Midland, Mich.). Process for Production of High Purity Cesium Metal and Cesium Compounds. U.S. Pat. 3,130,010, Apr. 21, 1964.

[11] Hurley, Thomas J., Jr., Richard O. MacLaren, and Ellsworth D. Whitney (assigned to Olin Mathieson Chemical Corp., Virginia). Alkali Metal Tetrafluorochlorates and Their Preparation. U.S. Pat. 3,143,391, Aug. 4, 1964.

[12] Lewis, Robert E. (assigned to U.S. Atomic Energy Commission). Method for Conversion of Cesium Alum to Radiation Source Material. U.S. Pat. 3,124,538, Mar. 10, 1964.

[13] Barton, Gerald B. (assigned to U.S. Atomic Energy Commission). Radioactive Cesium Containment, U.S. Pat. 3,161,601, Dec. 15, 1964.

[14] Prepared by Donald E. Eilertsen.

Prices.—Market prices per gram of various-grade gallium from bauxite sources are shown in table 5.

Foreign Trade.—General imports of gallium were 5 pounds, valued at $1,037, from France; 22 pounds, valued at $4,943, from Hungary; 11,253 pounds, valued at $3,846, from Mexico; 321 pounds, valued at $64,389, from Switzerland; 55 pounds, valued at $9,842, from the United Kingdom; and 14 pounds, valued at $3,056, from West Germany.

World Review.—*Germany, West.*—Gallium can be recovered from slime and scum arising from the electrorefining of aluminum. The dried slime can be reacted with hydrochloric acid and gallium recovered from the subsequent trichloride. *Japan.*—Mitsubishi Metal Mining Co. produces 99.999 to 99.9999 percent gallium metal, gallium trichloride (by distillation), and gallium sesquioxide (by hydro-oxidation of gallium trichloride), and also 99.999 percent gallium nitrate (by nitration of gallium hydroxide). The monthly potential production capacity of gallium was 10 kilograms.[17]

Technology.—The Bureau of Mines continued studies of extracting germanium and gallium from flue dust and began some studies on superconducting alloys, some of which contained gallium.

Numerous private organizations studied gallium intermetallic compounds, especially gallium arsenide and particularly its properties. Many reports were published and some discussed the electrical properties of gallium arsenide,[18] the fault formation of gallium

TABLE 5.—Market prices of gallium from bauxite sources in 1964

(Per gram)

Quantity	99.99 percent	99.999 percent	99.9999 percent
Up to 999 grams	$1.40	$1.50	$1.70
1,000 to 4,999 grams	1.20	1.30	1.50
5,000 to 24,999 grams	1.10	1.15	1.35
Over 25,000 grams	.95	1.00	1.20

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[15] National Aeronautics and Space Administration. Gallium is Useful Bearing Lubricant in High-Vacuum Environment. Brief 63–10337, May 1964.

[16] Electronic News. Greater Stress on Clad Items By Basic Suppliers Expected. V. 9, No. 468, Dec. 28, 1964, p. 24.

[17] Japan Society of Newer Metals. Current Situation of Newer Metals in Japan, 1964, pp. 20, 22.

[18] Black, J. Correlation of Electrical Measurements With Chemical Analysis in Zinc- and Cadmium-Diffused GaAs. J. Electrochem. Soc., v. 111, No. 8, August 1964, pp. 924–928.

Williams, Forrest V. The Effects of Orientation on the Electrical Properties of Expitaxial Gallium Arsenide. J. Electrochem. Soc., v. 111, No. 7, July 1964, pp. 886–888.

arsenide grown on germanium substrates,[19] the formation of arsenic trioxide on gallium arsenide during nitric acid etching,[20] a review of knowledge concerning diffusion in gallium arsenide,[21] and the diffusion of zinc into gallium arsenide.[22] Some other reports on gallium arsenide described the influence of zinc diffusions in vapor-grown gallium arsenide,[23] the preparation of high-resistivity gallium arsenide,[24] experiments on thermal etching and deposition on gallium arsenide using water vapor and hydrogen chloride gas,[25] and chromium doping methods to prepare high-resistivity gallium arsenide.[26]

Patents were issued on methods to purify alumina and simultaneously recover gallium,[27] extract gallium from ferric chloride,[28] prepare gallium from vaporized gallium trichloride,[29] produce gallium nitride,[30] manufacture high-purity gallium arsenide,[31] and make gallium alloys.[32]

GERMANIUM [33]

Germanium production from primary material in the United States continued to decrease as requirements of the electronic industry were obtained primarily from producers' inventories and reprocessing of scrap. Factory sales of semiconductor devices increased substantially and germanium continued to hold its share of the conventional applications. Import of metal and dioxide during the year was about one-fourth of that received in 1963, and producer and consumer inventories were reduced to a less burdensome level.

Domestic Production.—Production of germanium from primary materials of both foreign and domestic origin was estimated at 15,000 pounds. Refinery operation on new material was intermittent, and only at a rate sufficient to maintain the required supplement to material reprocessed from manufacturers scrap. Production from both primary materials and reprocessed scrap was approximately 80,000 pounds. The Eagle-Picher Co., Miami, Okla., and American Zinc Co., Fairmont, Ill., recovered germanium as a byproduct of domestic zinc ores. American Metal Climax, Inc., Carteret, N.J., and Sylvania Electric Products, Inc., Towanda, Pa., processed imported germanium-bearing raw materials. All of these producers reprocess scrap returned by the semiconductor manufacturers. In addition, Kawecki Chemical Co., Revere, Pa., and United Minerals and Chemical Corp., New Brunswick, N.J., operate scrap reprocessing facilities. Each of these producers supply germanium in the form of dioxide, first-reduction metal, and zone-purified metal. The Eagle-Picher Co. and Sylvania Electric Products, Inc., also supply germanium as single-crystal metal and as various chemical compounds.

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[19] Gabor, T. Epitaxial Growth of Gallium Arsenide on Germanium Substrates. J. Electrochem. Soc., v. 111, No. 7, July 1964, pp. 817–827.

[20] Kyser, D. F., and M. F. Millea. Etching of Gallium Arsenide With Nitric Acid. J. Electrochem. Soc., v. 111, No. 9, September 1964, pp. 1102–1103.

[21] Weisberg, Leonard R. Diffusion in GaAs. Trans. Met. Soc. AIME, v. 230, No. 2, March 1964, pp. 291–296.

[22] Becke, H., D. Flatley, W. Kern, and D. Stolnitz. The Diffusion of Zinc into Gallium Arsenide to Achieve Low Surface Concentrations. Trans. Met. Soc. AIME, v. 230, No. 2, March 1964, pp. 307–311.

[23] Silvestri, V. J., and F. Fang. Incorporation of Zinc in Vapor Grown Gallium Arsenide. J. Electrochem. Soc., v. 111, No. 10, October 1964, pp. 1164–1167.

[24] Woodall, J. M. High-Resistivity Gallium Arsenide. Electrochem. Technol., v. 2, Nos. 5–6, May–June 1964, pp. 167–169.

[25] Michelitsch, M., W. Kappallo, and G. Hellbardt. Reactions of Gallium Arsenide With Water Vapor and Hydrogen Chloride Gas. J. Electrochem. Soc., v. 111, No. 11, November 1964, pp. 1248–1253.

[26] Cronin, G. R., and R. W. Haisty. The Preparation of Semi-Insulating Gallium Arsenide by Chromium Doping. J. Electrochem. Soc., v. 111, No. 7, July 1964, pp. 874–877.

[27] Nagumo, Tadashi, and Masahiko Murakoshi (assigned to Asahi Kasei Kogyo Kabushiki Kaisha, Osaka, Japan). Process for Purifying Alumina and Recovering a Gallium Concentrate. U.S. Pat. 3,144,304, Aug. 11, 1964.

[28] Nagumo, Tadashi, Tokyo, Japan. Extraction of Gallium Using a Trialkyl Phosphate. U.S. Pat. 3,151,946, Oct. 6, 1964.

[29] Mayer, Alfred (assigned to Radio Corporation of America, Delaware). Method of Producing Gallium. U.S. Pat. 3,150,965, Sept. 29, 1964.

[30] Addamiano, Arrigo (assigned to General Electric Co., New York). Preparation of Nitrides of Aluminum and Gallium. U.S. Pat. 3,128,153, Apr. 7, 1964.

[31] Enk, Edward, Herbert Jacob, and Julius Nickl (assigned to Wacker-Chemie G.m.b.H., Munich, West Germany). Process for Manufacturing High Purity Gallium Arsenide. U.S. Pat. 3,129,059, Apr. 14, 1964.

[32] Bither, Jr., Tom Allan (assigned to E. I. du Pont de Nemours & Co., Inc., Wilmington, Del.). Ferromagnetic Mn-Ga Alloy and Method of Production. U.S. Pat. 3,147,112, Sept. 1, 1964.

Prosen, Emil, M. (assigned to Nobilium Products, Inc., Philadelphia, Pa.). Stainless Alloys Containing Gallium. U.S. Pat. 3,134,670, May 26, 1964.

————. Noble Metals Alloy Containing Gallium. U.S. Pat. 3,134,671, May 26, 1964.

[33] Prepared by Donald E. Moulds.

Consumption and Uses.—The commercial use of germanium continued to be confined essentially to the manufacture of semiconductor devices. Production of these devices utilizing germanium and high-purity silicon increased in quantity over the 1963 output. Improvement in manufacturing techniques, including reduction in unit size and ingot utilization, has increased consumption of the refined ingot in semiconductor components in recent years from 7 percent of germanium received to the present 15 percent. Improvement in scrap collection also has contributed toward the high degree of germanium utilization evident in the decreased requirement for new material in contrast to the increasing sales of semiconductor devices.

Small quantities of germanium were used in the manufacture of infrared optical glass, and fluorescent lighting, and in measuring devices such as high-sensitivity resistance thermometers. A thermoelectric alloy of germanium and silicon was being tested as a source of heat-electricity conversion for space power systems.

Prices.—Considerable pressure on germanium price developed during the year in view of high inventories and reduced demand for new material. The American Metal Market quoted price for the various grades, however, continued unchanged throughout the year. Price quotations, cents per gram, for the various grades in lots of 10 kilograms delivered to buyer's works were as follows:

Grade:	*Price (cents per gram)*
First reduction	25.20
Intrinsic quality	27.00
Single crystal	56.00
Dioxide, high-purity	15.10

Foreign Trade.—Imports of germanium dioxide in 1964 totaled 936 pounds valued at $46,600. Of the total, the Federal Republic of Germany supplied 484 pounds; the United Kingdom, 259 pounds; and Belgium-Luxembourg, 193 pounds. Belgium-Luxembourg also supplied the only metal imports, 76 pounds valued at $12,400. Germanium contained in waste and scrap, imported primarily from the Netherlands and Australia, amounted to 1,166 pounds, gross weight.

World Review.—*Belgium.*—Société Generale Metallurgique de Hoboken and the Société Vieille-Montagne de Balen continued to refine germanium in concentrates and germanium dioxide produced in the Republic of the Congo (Léopoldville) as a byproduct of the copper-zinc ores of Union Minière du Haut Katanga.

Italy.—Monteponi e Montevecchio Societi per Azioni produced germanium concentrate as a byproduct of electrolytic refining of zinc derived from the company mines.

Japan.—Four producers: Japan Electronic Metals Co., Tokyo Electronic Metals Co., Mitsui Mining and Smelting Co., Ltd., and Tokyo Denshi Yakin Laboratory, produced germanium metal and germanium dioxide. The refined germanium was derived from zinc ore processing, scrap reclamation, and imported concentrates and dioxide. Japan, a major consumer of germanium in semiconductor devices, imported 36,200 pounds of germanium dioxide, principally from Belgium, in 1961 but imports declined to 4,900 pounds in 1963 and a further decrease was indicated for 1964.

South-West Africa.—The Tsumeb Corp., Ltd. continued to produce germanium from the copper-lead-zinc ores of the Tsumeb mine. The germanium-rich concentrate is refined to dioxide and shipped to the United States and Belgium for further refining. The dioxide plant was shut down in September 1963 and was not operated during 1964.

Technology.—Stimulated by the demands for semiconductor materials of precisely determined degrees of purity, crystal structure, shape and size, a diversified research effort was continued on the basic properties of germanium and development of metallurgical techniques. The Germanium Research Committee continued to sponsor world-wide research projects and dissemination of information through the Germanium Information Center.[34]

The fundamentals of transistors and solid-state controls were described in simple engineering language.[35] Improvement in techniques of refining germanium metal from fly ash and scrap [36] and a method of classification of contact diodes by means of an analogue-digital computer [37] were reported in Czechoslovakian and Yugoslavian technical publications. Development of a new technique for slicing concave sections of material having ceramic characteristics and applicable to other high-cost materials was described.[38] The results of hydrometallurgical production of germanium from zinc ores of Mezica, Yugoslavia were reported by the University of Ljubljana.[39]

The use of lithium-drifted germanium detectors for high-resolution gamma spectroscopy was introduced [40] and phase equilibrium relations of lithium-germanium oxide reported.[41] The germanium cell conversion of incandescent energy to electrical energy was a promising development[42] and the electrical charateristics of germanium oxide films[43] and germanium-silicon alloy heterojunctions were reported.[44]

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[34] Germanium Research Center, c/o Midwest Research Institute, 425 Volker Bldg., Kansas City, Mo., 64110.

[35] Lujic, Ante. Who Needs Transistors. Product Engineering, v. 35, No. 6, Mar. 16, 1964, pp. 96–101.

[36] Technicky Tydenik (Prague). Production Formula for Germanium Oxide. June 24, 1964, p. 5.

[37] Techincke Novine (Belgrade). Production and Classification of Germanium Diodes. May 1, 1964, p. 5.

[38] Lipkins, Morton. Slicing High-Cost Materials. Ceram. Age, v. 80, No. 6, June 1964, pp. 74–76.

[39] Cazafura, Krsto, Janez Wohinz, and Jože Zakarjšek. Production of Germanium from Zinc Sulfide Ores. Rudarsko-Metalurski Zbornik (Yugoslavia), No. 3, 1963, pp. 261–271.

[40] Chemical and Engineering News. V. 42, No. 15, Apr. 13, 1964, p. 91.

[41] Murthy, M. Krishna, and J. Ip. Studies in Germanium Oxide System. J. Am. Ceram. Soc., v. 47, No. 7, July 1964, pp. 328–331; No. 9, Sept. 21, 1964, pp. 444–447.

The Bureau of Mines investigated the synthesis of compounds containing the system magnesia-magnesium fluoride-germania-lithium fluoride,[45] and germanium fluorphlogopite.[46] A report was published on low temperature heat capacities and entropies of germanium sulfide.[47]

U.S. patents were issued for a method of recovering germanium by the use of hydrochloric acid solution and ion exchanger resin,[48] and for a method of purifying germanium by fluxing with alkali metal and salts, and zone melting in a nonoxidizing atmosphere.[49]

GREENSAND[50]

In 1964, domestic production of greensand (glauconite) declined 37 percent in output tonnage and 28 percent in value compared to that of 1963. Only two companies were known to be operating: Kaylorite Corp. in Calvert County, Md., and Iversand Co. in Gloucester County, N.J. Statistics on production and sales for the year are not reported in order to avoid disclosing individual company confidential data. However, the average annual production for the 5-year period 1960–64 was 4,900 tons valued at $205,000. The marketed material was used as a soil conditioner and as a water softener.

Renewed interest was centered on glauconite deposits in Western Australia. The Secondary Industries Laboratory of the Commonwealth Scientific and Industries Research Organization at Perth, Australia, was investigating processes for extracting potash from glauconite. It was believed that large quantities of ore could be mined if required.[51]

INDIUM[52]

Domestic Production.—American Smelting and Refining Company, Perth Amboy, N.J., was the only domestic producer of indium. This firm also had plant facilities to produce indium chloride and indium sulfate. Indium production and shipments were smaller than in 1963.

Uses.—Indium was used in electronic devices in a variety of ways, such as soldering lead wires to germanium transistors, as a property-modifying component of the intermetallic semiconductor used for germanium transistors, in utilization of the magnetorestrictive and photodetective properties of indium arsenide and indium antimonide, and as an injection laser using indium phosphide as a semiconductor.

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[42] Product Engineering. V. 35, No. 15, July 20, 1964, p. 56.

[43] Wales, Robert D. The Electrical Characteristics of Germanium Oxidic Films. J. Electrochem. Soc., v. 111, No. 4, April 1964, pp. 478–480.

[44] Shewchun, J., and L. Y. Wei. Germanium-Silicon Alloy Heterojunctions. J. Electrochem. Soc., v. 111, No. 10, October 1964, pp. 1145–1149.

[45] McCormick, George R. The System Magnesia-Magnesium Fluoride-Germanium-Lithium Fluoride. BuMines Rept. of Inv. 6398, 1964, 11 pp.

[46] Miller, John L., Jr., M. V. Denny, and H. R. Shell. Synthesis and Properties of Germanium Fluorphlogopite. BuMines Rept. of Inv. 6443, 1964, 13 pp.

[47] Weller, W. W., and K. K. Kelley. Low-Temperature Heat Capacities and Entropies at 298.15° K of Sulfides of Arsenic, Germanium, and Nickel. BuMines Rept. of Inv. 6551, 1964, 7 pp.

[48] Stamberg, Jiri, and Josef Seidl. (Pardubice, Czechoslavakia). Chemical Manufacture of Germanium and Its Compounds. U.S. Pat. 3,144,397, Aug. 11, 1964.

[49] Porter, John L., Lynn Sciola, and John D. Sciola, (assigned to Sylvania Electric Products, Inc.). Method of Purifying Germanium. U.S. Pat. 3,163,523, Dec. 29, 1964.

[50] Prepared by Richard W. Lewis.

[51] Phosphorus and Potassium (London). Steady Increase in Potash Consumption in Australia. No. 11, June 1964, pp. 24, 26.

[52] Prepared by Harold J. Schroeder.

A significant use of indium was in sleeve bearings to promote resistance to corrosion and wear. Indium was also used in solders, in glass-sealing alloys, and in dental alloys.

Prices.—Effective October 1, 1964, prices for indium metal advanced 15 cents per troy ounce, and the new quotes were $2.40 per troy ounce for 30 to 90 troy ounces for stick shapes; in ingot shapes prices were $1.95 per troy ounce for 100 ounce lots and $1.65 per troy ounce for 10,000 and up lots.

Technology.—A report was published on the determination of certain magnetic and electric properties of lead-indium alloys in the type-II superconducting state.[53] A patent was granted on a process for improving the photosensitive properties of indium sulfide by addition of minor quantities of other elements and controlled heating.[54] Another patent was granted on use of a 90 percent indium-9 percent lead-1 percent antimony alloy to produce a PN-type junction for a semiconductor device.[55]

The anisotropic thermal expansions of different grades of indium and indium with small quantities of alloying metals were measured.[56] The vapor pressure of liquid indium was determined between the temperature range of 1,102° to 1,422° K[57] and another study confirmed the suspected atmospheric corrosion fatigue of indium plated on a lead substrate.[58] Diffusion between indium and gold below the melting point of indium was shown to occur in definite phase equilibrium zones.[59]

An advanced method of constructing a superconducting magnet utilized an indium dipped cable splicing technique to provide the electrical interconnection.[60] The Naval Research Laboratory has developed an accurate polarographic procedure for determination of lead in indium as part of their thermoelectric studies. The National Aeronautics and Space Administration has described the use of indium foil with a beryllia washer to improve heat dissipation and reduce assembly strains in mounting power transistors in a vacuum environment.

MEERSCHAUM [61]

Virtually the sole use of meerschaum, the mineral sepiolite, was in the manufacture of smokers' accessories, such as pipe bowls and cigar and cigarette holders. In 1964, consumers continued to rely upon foreign sources for their raw material supplies; no domestic production of meerschaum has been reported since about 1914.

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[53] Druyvesteyn, W. F., and J. Volger. Resistance Transitions of Superconducting Lead-Indium Alloys. Philips Research Reports (Netherlands), v. 19, No. 4, August 1964, pp. 359–377.

[54] Offergeld, Georges, and Jean Leon Van Cakenberghe. (assigned to Union Carbide Corp., New York). Process for Treating Photosensitive Indium Sulfide Compositions. U.S. Pat. 3,124,426, May 25, 1961.

[55] Tomono, Masami, Takeshi Tadagi, Tadasi Tokuyama, and Eisaburo Yamada, (assigned to Kabushiki Kaisha Hitachi Seisakusho, Tokyo, Japan). Method of Producing PN Junctions. U.S. Pat. 3,154,445, Oct. 27, 1964.

[56] Smith, J. G., and V. L. Schneider. Anisotropic Thermal Expansion of Indium. J. Less-Common Metals (Netherlands), v. 7, No. 1, July 1964, pp. 17–22.

[57] Herrick, C. C. Vapor Pressure of Liquid Indium. Trans. Met. Soc. AIME, v. 230, No. 6, October 1964, pp. 1439–1442.

[58] Journal Less-Common Metals (Netherlands). Atmospheric Corrosion Fatigue of Indium. V. 7, No. 1, July 1964, pp. 84–85.

[59] Powell, G. W., and J. D. Braun. Diffusion in the Gold-Indium System. Trans. Met. Soc., AIME, v. 230, No. 4, June 1964, pp. 694–699.

[60] Electronic News. V. 9, No. 467, Dec. 21, 1964, p. 30.

[61] Prepared by E. C. Peterson.

Meerschaum imports for consumption totaled 29,202 pounds valued at $37,036 in 1964 compared with 19,414 pounds valued at $23,491 in 1963. Turkey supplied 97 percent of the 1964 imports with France supplying the remaining 3 percent.

Turkey continued to be the principal world source of meerschaum.

In Tanganyika during periods of high-water table, the Tanganyika Meerschaum Corp., Ltd., has considerable difficulty in mining meerschaum. The company, in an effort to continue operations during these periods, has successfully reconstituted meerschaum found in waste piles at the mining sites. When properly processed, the reconstituted material has many of the properties of high-grade block meerschaum.[62]

Meerschaum for local consumption was mined from small high-grade sepiolite deposits in the southern region of the Somali Republic.

A new sepiolite grinding plant was under construction near Madrid, Spain. The facility, using material recovered from the nearby San Miguel mine was expected to be in operation some time during 1964.[63]

RADIUM [64]

No domestic production of primary radium was reported in 1964, but there was some domestic activity in reprocessing secondary radium. The use of radioisotopes produced in nuclear reactors continued to grow, but radium continued to be preferred for some uses, particularly in medical applications. International activity in radium sales and shipments was obscured by inclusion of radium and radioisotope imports in a tariff classification recorded only by millicuries and value.

Legislation and Government Regulations.—Although it was estimated that radium was used in at least 4,500 facilities throughout the United States, regulations of the U.S. Atomic Energy Commission (AEC) did not include control over its possession and use. Only 16 States, under their radiological health programs, licensed, registered, or inspected radium facilities, but not all were comprehensive in scope. A program initiated by a division of Public Health Service, U.S. Department of Health, Education, and Welfare, was expected to help the various States in planning proper radium management.[65]

Domestic Production.—No domestic concerns reported production of radium; most of the small internal requirements were satisfied by imports. Companies distributing radium, its derivatives, and related compounds were Canadian Radium & Uranium Division, Canrad Precision Industries, Inc., and Radium Chemical Co., Inc., New York; and United States Radium Corp., Morristown, N.J. Radium Chemical distributed radium for the Belgian processor of Congolese ores, Union Minière du Haut-Katanga. Atomic Energy of Canada, Ltd., which holds stocks of radium, was represented in the United States by A. Bruce Edwards, Bala-Cynwyd, Pa.

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[62] Skillings' Mining Review. Meerschaum Success. V. 53, No. 29, July 18, 1964, p. 19.
[63] Mining Journal (London). V. 262, No. 6701, Jan. 24, 1964, p. 69.
[64] Prepared by John G. Parker.
[65] Villforth, John C. Problems in Radium Control. Public Health Reports, v. 79, No. 4, April 1964, pp. 337–342.

Consumption and Uses.—Cheaper, artificially produced radioisotopes increasingly replaced radium for most applications. The most important use for radium still was in medicine, particularly by physicians who use sealed radiation sources for radiation therapy in treating cancer. Cobalt 60 and iridium 192, however, received special attention in radiotherapy. Industrial radiography, such as oil-well logging, used iridium 192, cobalt 60, thulium 170, and cesium 137. Neutron sources were activated in many cases by polonium 210, plutonium 239, americium 241, and antimony 124. Many luminescent compounds contain hydrogen 3 (tritium), krypton 85, or promethium 147 instead of radium-activated phosphors. Static elimination equipment used polonium and americium.

Prices.—Quotations by Steel on newly processed radium, usually in the form of the sulfate and sometimes as the bromide, were from $16.00 to $21.50 per milligram of contained radium. It was reported that small gram quantities of radium bromide, reprocessed from older stocks, were available at about $4 per millicurie ($4 per milligram of radium).

Foreign Trade.—A new tariff classification, adopted in 1963, groups radium with other useful radioactive elements, isotopes, and compounds, but excludes those of natural uranium and thorium. From available information, it is probable that the quantity of radium imported from Belgium-Luxembourg decreased but that unit values increased over 15 percent. Exports of metal and alloys only to Canada contained 177 milligrams of radium worth $2,360.

Technology.—Radioactive waste disposal problems led to efforts in removing and determining the disposition of radium and other contaminants from radioactive wastes. Barium sulfate, with artificially induced calcium defects in its crystal lattice, was used to precipitate radium and strontium from radioactive wastes.[66] In research on carbonate leaching by the Bureau of Mines it was found that over 95 percent of radium 226 was precipitated with uranium, with no buildup of radium 226 in the pregnant solution.[67] A radiochemical method was described for separating radium 223 (actinium X) from uranium ore and using it as a tracer in analyzing for radium 226.[68]

In a method devised for producing a large radium-beryllium neutron source, $RaCO_3$ was mixed with powdered beryllium, fritted, placed in an inner platinum casing, compressed, sealed, and placed in an outer steel casing.[69] A remote control method was developed for producing a ZnS:Cu luminophor, using radium chloride or a synthetic radioisotope as an activator.[70]

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[66] Berak, Lubomir. Decontamination of Waste Polluted With Radium and Radiostrontium. Czechoslovakian Pat. 110,625, Apr. 15, 1964; Chem. Abs., v. 61, No. 5, Aug. 31, 1964.

[67] Tame, K. E. Radioactivity in Alkaline Leach Milling Processes. BuMines Rept. of Inv. 6346, 1964, 8 pp.

[68] Butaye, Michel. Isolement d'un traceur pour l'analyse radiochimique du radium 226 (The Separation of a Tracer for the Radiochemical Analysis of Radium 226). Commissariat a l'Energie Atomique. Centre d'Etudes Nucleaires, Saclay, France. March 1964, 7 pp. Nuclear Sci. Abs., v. 18, No. 12, June 30, 1964, p. 2675.

[69] Fredrich, Bedrich, and Josef Kott. New Method of Manufacture of a Large Neutron Source of the Ra-Be Type. Jaderna Energie, v. 10, 1964, pp. 295–297; Chem. Abs., v. 61, No. 12, Dec. 7, 1964, pp. 14144h–14145a.

[70] Plander, Emil. Radioactive Luminescent Paints. Czechoslovakian Pat. 109,483, Jan. 15, 1964, 3 pp.; Chem. Abs., v. 60, No. 11, May 25, 1964, p. 13451b.

RHENIUM[71]

Considerable interest in the use of rhenium as an alloying addition to tungsten and molybdenum was exhibited during the year, and several companies developed and offered tungsten-rhenium alloys in commercial quantities. Consumption of rhenium metal during 1964 increased substantially and was approximately three times greater than that reported in 1963.

Domestic Production.—A secondary byproduct, rhenium concentrate continued to be recovered entirely from the molybdenite associated with southwestern porphyry copper ores. Chase Brass & Copper Co., Inc., Waterbury, Conn. (a subsidiary of Kennecott Copper Corp), and the Department of Chemistry, University of Tennessee, Knoxville, Tenn., continued to be the only domestic producers of rhenium. Rhenium salts were recovered from the molybdenite obtained from porphyry copper ores by the Shattuck Chemical Co., Denver, Colo., and the Molybdenum Corporation of America, Washington, Pa. A report describing the current methods employed by the domestic industry in the recovery and refining of rhenium was presented at the annual meeting of the AIME in New York.[72]

Production, consumption, and shipments of domestic rhenium metal, alloys, and compounds continued to increase, and spurred by the demand for rhenium in refractory metal alloys, reached an alltime high. Domestic production of recovered rhenium increased slightly over the estimated production of 1,400 pounds reported in 1963,[73] while production of rhenium metal increased significantly. In this report,[74] it was indicated that Chase Brass & Copper Co., Inc., has the potential capacity for readily increasing production of recovered rhenium to 4,000 to 5,000 pounds per year.

Kennecott Copper Corp., Salt Lake City, Utah, announced plans for the construction of a new molybdenite roasting facility at Garfield, Utah, to go onstream early in 1966. This facility will have an annual capacity of 10 million pounds of molybdenite and will include a rhenium recovery circuit.

Consumption and Uses.—Approximately 1,500 pounds of rhenium metal was consumed, primarily in tungsten-rhenium (W-Re) alloys, representing an increase of about three times compared with 1963 consumption. The choice by the U.S. Atomic Energy Commission (AEC) of the tungsten-25 percent rhenium alloy for use as a structural material for many nuclear reactors has greatly stimulated the production and consumption of rhenium metal. The addition of rhenium to tungsten- and molybdenum-base alloys lowers the ductile-brittle transformation temperature and imparts sufficient ductility to allow the alloys to be formed at room temperature with standard fabrication equipment while still retaining exceptional high-temperature, high-strength properties. Approximately 80 to 85 percent of the rhenium consumed during the year was used in refractory alloys, predominantly tungsten-rhenium alloys. Other applications of rhenium continued to be in electrical contacts, thermocouples, catalysts, and coatings. One of the first commercial applications of rhenium was as a tungsten-3 percent rhenium alloy wire for flashbulb filaments which has a higher resistivity and faster ignition than does pure tungsten. The addition of 3 percent rhenium allows the tungsten alloy to be easily drawn to filament wire at room or slightly elevated temperatures.

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[71] Prepared by Richard F. Stevens, Jr.

[72] Davenport, William H. Rhenium Sources and Methods of Extracting and Refining. Pres. at annual AIME meeting, New York (published by Chase Brass & Copper Co., Inc.), February 1964, 40 pp.

[73] Port, John H. Rhenium and Rhenium Alloy Technology. Pres. at annual AIME meeting, New York (published by Chase Brass & Copper Co., Inc.), February 1964, 28 pp.

[74] Page 2 of work cited in footnote 73.

Prices.—Chase Brass & Copper Co., Inc., quoted the following prices for various rhenium materials, minimum order $50. Ammonium perrhenate (NH_4ReO_4), $425 per pound up to 5 pounds, and $400 per pound for larger quantities; potassium perrhenate ($KReO_4$), $395 per pound up to 5 pounds, and $370 per pound for larger quantities; rhenium metal powder, grade I, $650 per pound up to 1 pound, and decreasing to $580 per pound for lots of 20 or more pounds; and rhenium sintered bar (melting stock), $800 per pound up to 1 pound and decreasing to $750 per pound for lots of 5 or more pounds. Rhenium rod having diameters ranging from 0.2 to 0.025 inches were quoted at $900 to $1,260 per pound, respectively, and rhenium strip having thicknesses ranging from 0.06 to 0.001 inches were quoted at $815 to $1,580 per pound, respectively. Also available were molybdenum-rhenium and tungsten-rhenium alloys in ingot, wire, rod, sheet, and tubing produced by both standard powder metallurgy (PM) and arc-melting (AM) techniques.

Foreign Trade.—During 1964, 211 pounds of high-purity rhenium metal powder valued at $97,407 was imported from West Germany (99 percent) and the United Kingdom (1 percent), primarily for use in high-temperature tungsten-rhenium thermocouple alloys and electronics applications. The rhenium metal imported from West Germany continued to be sold at approximately $20 per pound less than domestic rhenium.

Technology.—In cooperation with the AEC, the Bureau of Mines continued studies of the tungsten-25 percent rhenium alloy to determine its properties and optimum methods of consolidating and fabricating it into small diameter, thin-walled tubing.[75]

The Bureau of Mines and Oak Ridge National Laboratory (ORNL) conducted similar but independent studies on the vapor codeposition of tungsten and rhenium from their halides. Experiments showed that rocket nozzles of rhenium-coated graphite could be successfully lined with a thin, uniform coating of tungsten by vapor deposition.[76]

Studies were conducted at ORNL for AEC on the production of W-25Re alloys for use as reactor structural materials by codepositing these metals for their halide vapors.[77] Studies of the production of rhenium coatings by both chemical and vapor deposition were also conducted.[78]

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[75] Bureau of Mines. Metallurgical Progress Report, No. 25. U.S. Dept. of Commerce, Clearinghouse for Federal Scientific and Technical Information, USBM–RC–1150, December 1964, 23 pp.

[76] Hoerter, F. W. Vapor Deposition of Tungsten on MERM Rocket Nozzles. BuMines Rept. of Inv. 6464, 1964, 19 pp.

[77] U.S. Atomic Energy Commission. Metal and Ceramics Division, Annual Report for Period Ending 30 June, 1964. U.S. Dept. of Commerce, Clearinghouse for Federal Scientific and Technical Information, ORNL–3670, November 1964, 317 pp.

[78] U.S. Atomic Energy Commission. Reactor Materials. V. 7, Nos. 1–4, U.S. Government Printing Office, 1964, 282 pp.

Extensive studies of neutron irradiation upon tungsten-rhenium alloys were conducted to determine the effect of neutron bombardment on the alloys when used as reactor structural components.[79] In contrast to the effects on high-temperature iron and nickel alloys, the irradiation of W-Re alloys strengthened the materials, increased the time to rupture by 280 percent and did not appreciably reduce the ductility.[80]

Further evaluation of tungsten-rhenium (25–30 percent Re) and molybdenum-rhenium (50 percent Re) alloys was conducted for AEC by other contractors and optimum quality alloys were developed by powder metallurgy techniques for use at 3,000° C. Methods were developed to prepare W-Re seamless tubing by coextrusion at 1,800° C using a molybdenum cladding to provide lubrication.[81]

The tungsten-rhenium alloys were found to be compatible with various nuclear fuels (UC, UN, and UO_2) and with liquid lithium and cesium used as heat transfer mediums.[82]

The W–25Re alloy initially produced by powder metallurgy (PM) techniques is now also being produced with high purity by vacuum arc melting (AM).[83] The purity and homogeneity of this alloy give it unprecedented ductility at room temperature and at −300° F. At 2,400° F, its ultimate strength is over 100,000 psi.

Technetium (Tc), a constitutent of the waste fission products of nuclear reactors, and consequently having a large potential supply, is in the same periodic group as rhenium and has similar properties. Because of its similarity and more abundant supply, technetium was being studied as an alloying addition to tungsten to replace rhenium, which is a rare element.[84] Eight hundred grams of purified technetium metal was reduced from technetium salts recovered by anion exchange from the waste fission products of uranium and plutonium reactors. A series of 18 tungsten-technetium (W-Tc) alloys containing 0, 2.5, 5, 10, 20, 30, 40, 50, and 60 atomic percent (a/o) Tc were compacted prior to consolidation by arc- or electron-beam melting. Four pure Tc compacts and three W-Tc alloys (30, 40, and 50 a/o Tc) were melted and are in the process of being fabricated to sheet to determine the workability of pure technetium and the effects of technetium additions on the workability of tungsten.[85]

Preliminary results of this investigation indicated that, like the W-Re alloys, the W-Tc alloys should be able to be worked at room temperature using standard fabrication equipment and that the slight beta radioactivity of technetium (20 microcuries per gram) is shielded by alloying. The alloys of major interest in this study are those which contain 25 to 30 a/o Tc. Because of its lower atomic weight (99 for Tc versus 186.2 for Re) it is anticipated that one part of technetium will replace two parts of rhenium in tungsten alloys. A second advantage of using Tc alloys in nuclear reactors is its lower thermal neutron cross-section (22 barns) compared with rhenium (85 barns) which will cause a decrease in the absorption of neutrons and a consequent increase in reactor efficiency.

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[79] Page 189 of work cited in footnote 78.

[80] Rice, William L. R. Nuclear Fuels and Materials Development. U.S. Dept. of Commerce, Clearinghouse for Federal Scientific and Technical Information, TID–11295, 3d ed., July 1964, 321 pp.

[81] Pages 210–215 of work cited in footnote 80.

[82] DeMastry, J. A. Investigation of High-Temperature Refractory Metals and Alloys for Thermionic Converters. Defense Documentation Center AD 442960, July 10, 1964, 20 pp.

[83] Materials in Design Engineering. Tungsten-Rhenium Alloy is Ductile at −300° F. V. 59, No. 5, May 1964, pp. 122, 124.

[84] General Electric Co., Hanford Atomic Products Operation. Quarterly Report, A Study of Tungsten-Technetium Alloys. U.S. Dept. of Commerce, Clearinghouse for Federal Scientific and Technical Information, HW–83550 (Accession No. N64–33157), July 14, 1964, 4 pp.

[85] General Electric Co., Hanford Atomic Products Operation. Quarterly Report, A Study of Tungsten-Technetium Alloys. U.S. Dept. of Commerce, Clearinghouse for Federal Scientific and Technical Information, HW–84309, Oct. 1, 1964, 11 pp.

Battelle Memorial Inst., Pacific Northwest Laboratories. A Study of Tungsten-Technetium Alloys, Second Year Effort. U.S. Dept. of Commerce, Clearinghouse for Federal Scientific and Technical Information, HW–84486, Nov. 5, 1964, 10 pp.

General Electric Co., Hanford Atomic Products Operation. Quarterly Progress Report, A Study of Tungsten-Technetium Alloys. U.S. Dept. of Commerce, Clearinghouse for Federal Scientific and Technical Information, HW–84550, Jan. 1, 1965, 21 pp.

Studies were conducted in an attempt to develop a rhenium diffusion barrier by vapor deposition on a columbium-base alloy between the chromium-titanium-silicide (Cr-Ti-Si) coating and the alloy substrate.[86] However, the vapor-deposited rhenium was poorly bonded and exhibited a cellular surface structure.

The effects of grain-size upon the twinning stresses of two chromium-rhenium alloys were studied.[87] When the grain size of the Cr-35Re and Cr-15Re alloys were plotted against the tensile twinning stress, the slope of the Cr-35Re line was found to be negative while that for the Cr-15Re alloy was positive. Examinations of the alloy microstructures indicated that in the Cr-15Re alloy deformation twins were generated at precipitates located in grain boundries, however, even at a magnification of 100,000 X, there was complete lack of visible precipitates in the Cr-35Re alloy.

Wire of molybdenum alloyed with 50 percent rhenium (Mo-50Re), because it is ductile at high temperatures, is being used to replace pure molybdenum wire which becomes brittle and fractures when used at temperatures approaching 3,000° F. in the resistance heaters of gas pressure-bonding autoclaves.[88] Although all Mo-Re alloys exhibit high electrical resistivity values, only the Mo-50Re alloy has the necessary ductility after recrystallization. Wires of this alloy are readily repairable and ductile welds can be achieved with or without an inert gas atmosphere.

SCANDIUM [89]

Domestic Production.—American Scandium Corp., Newton Station, Cincinnati, Ohio, recovered scandium metal and scandium oxide from uranium mill residue. Research Chemicals Division of Nuclear Corporation of America, Phoenix, Ariz., produced some purified scandium oxide and scandium metal. Output figures for these firms were company confidential. Atomergic Chemetals Co., Division of Gallard-Schlesinger Chemical Manufacturing Corp., Carle Place, Long Island, N.Y., produced between 5 and 10 pounds of scandium metal from scandium oxide.

Uses.—One of the best known uses for scandium was in radioisotope tracers for oil well drilling and analytical work. The largest use for scandium was probably in research and development of applications.

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[86] Moore, V. S., and A. R. Stetson. Evaluation of Coated Refractory Metal Foils. Defense Documentation Center AD 429810, Washington, D.C., Jan. 20, 1964, 92 pp.

[87] Rosenfield, A. R. Deformation Twinning of Polycrystalline Chromium-Rhenium Alloys. J. Less-Common Metals (Netherlands), v. 7, No. 3, September 1964, pp. 235–238.

[88] Materials in Design Engineering. Molybdenum-Rhenium Wire Lasts Long at 3,000° F. V. 59, No. 3, March 1964, pp. 176–178.

[89] Prepared by Donald E. Eilertsen.

Several new uses for scandium compounds were reported.[90] Scandium carbide had potential use as high-temperature semiconductor material. Scandium nitride crucibles were used to prepare single crystals of gallium arsenide or phosphide. Scandium oxide had uses in glass compositions to reduce density and to open up the structure, as flame spray material for various surfaces to resist heat and thermal shock reportedly better than zirconia, alumina, and magnesia, and as knife edges on laboratory balances where its performance reportedly excells sapphire.

Other uses reported for scandium compounds include utilization in growing garnets for microwave applications, and application in television tube phosphors in conjunction with europium oxide.

Prices.—Prices quoted on scandium metal and scandium oxide by Research Chemicals, Division of Nuclear Corporation of America, Phoenix, Ariz., are shown in table 6.

TABLE 6.—Market prices of scandium metal and scandium oxide in 1964

Item	Quantity and price		
	1 to 99 grams, per gram	100 to 453 grams, per gram	1 to 2 pounds, per pound
Scandium metal:			
99.0 percent	$15.70	$13.50	$5,123
99.9 percent	16.60	14.25	5,393
Scandium oxide:			
99.0 percent	5.35	4.37	1,520
99.9 percent	5.63	4.60	1,600

World Review.—*New Zealand.*—Ultrabasic pyroxenite formations of South Island were reported to contain 100 and occasionally 120 parts per million of scandium. In comparison, Australian uranium tailings contain 30 parts per million of scandium. Foreign firms were sought to develop the deposits.[91]

Technology.—Scandium recovery from uranium plant iron sludge and from wolframite concentrate was reported. Sludge containing 0.14 percent scandium yielded a product containing 99.6 percent scandium oxide with recovery at 90 percent, whereas wolframite containing 0.058 percent scandium yielded a product containing 99.9 percent scandium oxide with recovery at 83 percent.[92]

The scandium-gadolinium alloying system was developed.[93] The crystal structure of scandium tricadmium was studied.[94] The preparation, crystal structures, and densities of calcium scandate ($CaSc_2O_4$) and strontium scandate ($SrSc_2O_4$) were reported.[95] The separation of scandium from yttrium and rare-earth metals analytically by cation exchange chromatography was described.[96]

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[90] Ceramic Industry. Materials for Ceramic Processing. V. 84, No. 1, January 1965, p. 135.

[91] Bureau of Mines. Mineral Trade Notes. V. 59, No. 6, December 1964, p. 37.

[92] Ross, J. R., and C. H. Schack. Recovery of Scandium from Uranium Plant Iron Sludge and From Wolframite Concentrates. BuMines Rept. of Inv. 6580, 1965, 22 pp.

[93] Beaudry, J. B., and A. H. Daane. The Sc–Gd System. J. Less-Common Metals (Netherlands), v. 6, No. 4, April 1964, pp. 322–325.

[94] Schablaske, R. V., and M. G. Chasanov. The Crystal Structure of $ScCd_3$. Trans. Met. Soc. AIME, v. 230, No. 1, February 1964, pp. 248–249.

[95] Carter, J. R., and R. S. Feigelson. Preparation and Crystallographic Properties of $A^2+B_2^3+0_4$ Type Calcium and Strontium Scandates. J. Am. Ceram. Soc., v. 47, No. 3, March 1964, pp. 141–144.

Patents were issued for a method to separate scandium from mixtures of scandium and thorium,[97] and a process to prepare scandium hydrides.[98]

SELENIUM [99]

Production of selenium increased less than 1 percent and shipments decreased 5 percent. The price remained steady. Selenium was used principally in rectifiers.

The Office of Emergency Planning increased the conventional war stockpile objective for selenium on April 17 to 475,000 pounds. This new objective reflects a new policy which accords with the recommendations of the Executive Stockpile Committee to establish a single objective for materials in the national stockpile. On December 31, total Government-owned inventories were 387,355 pounds, 81.5 percent of the objective. Inventories showed 97,100 pounds in the national strategic stockpile, 42,253 pounds in the CCC stockpile, and 248,002 pounds in the supplemental stockpile.

Domestic Production.—Companies reporting selenium production, shipments, and stocks were American Metal Climax, Inc., Carteret, N.J.; American Smelting and Refining Company, Baltimore, Md.; International Smelting & Refining Co., Perth Amboy, N.J.; Kawecki Chemical Co., Boyertown, Pa.; and Kennecott Copper Corp., Magna, Utah. Kawecki Chemical is a manufacturing chemical company. The other four companies produced selenium as a byproduct of the electrolytic refining of copper.

TABLE 7.—Salient selenium statistics

(Thousand pounds of contained selenium)

	1955–59 (average)	1960	1961	1962	1963	1964
United States:						
Production [1]	900	539	1,022	999	928	929
Shipments to consumers	809	552	787	741	679	646
Imports	197	162	117	159	339	293
Consumption, apparent [2]	1,006	714	904	900	1,018	939
Stocks, Dec. 31, producers	362	273	515	773	1,022	1,305
Price per pound, commercial grade	$7.10–$10.10	$6.50–$7.00	$5.75–$6.25	$5.75–$6.25	$4.50–$5.75	$4.50–$6.00
World: Production	1,796	1,671	2,095	[r] 2,060	[r] 2,071	2,102

[r] Revised.
[1] Includes small quantity of secondary selenium, 1955–61.
[2] Measured by shipments plus imports.

Consumption and Uses.—Sodium selenate was used as an additive in chromium plating solutions to improve the quality of the chromium plate by increasing the number of microcracks in the plate. It was reported that the chromium plate is characterized by a large number of microcracks, which are continuously connected to provide an area of low anodic current density and a correspondingly slow uniform rate of corrosion.[1]

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[96] Strelow, F. W. E., and C. J. C. Bothma. Separation of Scandium From Yttrium, Lanthanum, and the Rare Earths by Cation Exchange Chromatography. Anal. Chem. v. 36, No. 7, June 1964, pp. 1217–1220.

[97] Moore, James D., and Norma N. Schiff (assigned to Vitro Corporation of America, New York, N.Y.). Process for Separating Scandium from Mixtures Containing Scandium and Thorium Values. U.S. Pat. 3,146,063, Aug. 25, 1964.

[98] Kempter, Charles P., and Joseph C. McGuire (assigned to U.S. Atomic Energy Commission). Preparation of Scandium Hydrides. U.S. Pat. 3,152,868, Oct. 13, 1964.

[99] Prepared by Arnold M. Lansche.

Selenium was used in electronic applications, xerography, photoluminescent products, glass, rubber, and alloy steel, and as a catalyst in the processing of organic materials. Silicon competed successfully with selenium in 1964 for a larger share of the rectifier market.

Stocks.—The stocks of selenium at producers' plants has increased an average of 258,000 pounds annually since 1960.

Prices.—During 1964 selenium was quoted at $4.50 per pound for the commercial grade and $6 per pound for the high-purity grade. Ultrahigh-purity selenium (99.999+ percent) sold for $13 to $20 per pound; on the basis of contained selenium, ferroselenium was quoted at $4.50 per pound.

Foreign Trade.—Imports of selenium metal and compounds from Canada were 214,700 pounds valued at $1,013,468. Total imports from other countries were Belgium-Luxembourg, 17,700 pounds; France, 200 pounds; West Germany, 23,400 pounds; Japan, 28,700 pounds; Peru, 4,100 pounds; Sweden, 200 pounds; and the United Kingdom, 4,000 pounds.

World Review.—*Bulgaria.*—The output of selenium was reported to have been increased 5 percent at the Georgi Danyanov copper smelter at Pirdop.

Canada.—Selenium was a byproduct of the electrolytic copper refineries of the International Nickel Company of Canada, Ltd., Copper Cliff, Ontario, and Canadian Copper Refiners, Ltd., Montreal East, Quebec.

Japan.—The exclusive right to distribute exports of selenium from Japan was given to Mining & Chemical Products Ltd., London.[2] Annual production of selenium in Japan has increased each year since 1957.

Mexico.—Selenium was a byproduct of lead flue dust obtained at the American Smelting and Refining Company smelter at Chihuahua. The selenium was refined in Mexico.

Zambia.—Selenium in anode slimes obtained from the electrolytic refining of copper in Zambia was shipped to Belgium and the United States for refining.

Technology.—Research has shown that the organoselenium compounds selenomethionine and selenocystine help to protect amino acids and protein components in living organisms from gamma radiation damage.[3]

Some of the thermodynamic properties of the semiconductor compounds SB_2Se_3, Bi_2Se_3, Sb_2Te_3, and Bi_2Te_3 were reported in 1964.[4] The heats of formation were determined in a liquid metal solution cal-

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[1] Sodium Selenate as an Additive for Superior Chromium Plate. Bulletin No. 2, Selenium-Tellurium Development Association, Inc., New York.

[2] Metal Bulletin (London). MCP and Japan's Selenium. No. 4925, Aug. 28, 1964, p. 23.

[3] Shimazu, F., and A. L. Tappel. Selenoamino Acids: Decrease of Radiation Damage to Amino Acids and Proteins. Science, v. 143, No. 3604, Jan. 24, 1964, pp. 369–371.

[4] Howlett, B. W., Somnath Misra, and M. B. Bever. On the Thermodynamic Properties of the Compounds Sb_2Se_3, Bi_2Se_3, Sb_2Te_3, and Bi_2Te_3. Trans. Met. Soc. AIME, v. 230, No. 6, October 1964, pp. 1367–1372.

TABLE 8.—Free world production of selenium by countries[1]

(Pounds)

Country	1955–59 (average)	1960	1961	1962	1963	1964 [p]
North America:						
Canada	350,797	521,638	430,612	487,066	468,772	448,750
Mexico	125,313	6,944	5,642	6,953	6,336	[e] 9,000
United States	899,950	539,000	1,022,000	999,000	928,000	929,000
South America: Peru	6,962	10,681	16,305	18,382	19,790	16,797
Europe:						
Belgium-Luxembourg (exports)	68,122	72,531	51,808	29,542	54,013	[e] 94,100
Finland	10,290	11,358	13,296	11,797	15,417	14,500
Sweden	133,793	176,809	213,846	154,322	[e] 198,400	[e] 198,400
Asia: Japan	171,239	278,234	300,262	309,314	313,494	330,335
Africa: Zambia (formerly Northern Rhodesia)	26,251	50,119	38,292	40,526	62,891	57,631
Oceania: Australia	2,808	[e] 3,500	[e] 3,000	[e] 3,500	[e] 3,500	[e] 3,500
World total[1]	1,796,000	1,671,000	2,095,000	2,060,000	2,071,000	2,102,000

[e] Estimate. [p] Preliminary.

[1] This table incorporates a number of revisions of data published in previous Selenium chapters. Data do not add exactly to totals shown because of rounding.

orimeter using bismuth as the solvent. The heat capacities near the melting point, the heats of fusion, and the melting points of Sb_2Te_3 and Bi_2Te_3 were determined.

Patents were issued on a process for applying a protective plastic coat to the vitreous selenium layer of a xerographic plate,[5] and a method was developed for removal of selenium values from industrial solutions in such a way that plugging of the scrubber system is eliminated and recovery of selenium can be made under controlled conditions.[6]

Battelle Memorial Institute, Columbus, Ohio, issued monthly abstracts of technical reports concerning selenium and tellurium.

STAUROLITE[7]

Staurolite, an aluminum-iron silicate used as an additive in portland cement mixtures or as an abrasive for sand blasting, was one of the several minerals extracted from sand in Clay County, Fla., by E. I. du Pont de Nemours & Co., Inc. Staurolite sales in 1964, while 10 percent more in quantity and 8 percent higher in total volume than in 1963, were 32 percent under the peak volume of 1960.

TELLURIUM[8]

World tellurium production dropped to the lowest level since 1959 and domestic output was the lowest since 1958.

Domestic Production.—The primary source of tellurium was as a byproduct of electrolytic copper refining and lead refining. A small quantity was recovered from scrap.

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[5] Kinsella, John J. (assigned to Xerox Corp., Rochester, N.Y.). Process for Adhering Plastic to Vitreous Selenium. U.S. Pat. 3,146,145, Aug. 25, 1964.

[6] Prater, John D., Archibald W. Maynard, William M. Tuddenham, and Clifford E. Selin (assigned to Kennecott Copper Corp., New York, N.Y.). Handling of Solutions Containing Selenium Values. U.S. Pat. 3,130,012, Apr. 21, 1964.

[7] Prepared by J. Robert Wells.

[8] Prepared by Arnold M. Lansche.

Companies that reported production, shipments, and stocks were American Metal Climax, Inc., Carteret, N.J.; American Smelting and Refining Company, Baltimore, Md.; International Smelting & Refining Co., Perth Amboy, N.J.; Kawecki Chemical Co., Boyertown, Pa.; Phelps Dodge Refining Corp., New York; and United States Smelting, Refining, and Mining Co., East Chicago, Ind. Penn Rare Metals, Inc., which has reported production of tellurium in previous years, was bought by Kawecki Chemical Co. in January 1964.

TABLE 9.—Salient tellurium statistics

(Thousand pounds of contained tellurium)

	1955–59 (average)	1960	1961	1962	1963	1964
United States:						
Production, primary and secondary	182	271	205	264	201	145
Shipments to consumers	204	228	231	233	134	122
Stocks, Dec. 31, producers	112	126	64	87	141	162
Imports	NA	15	NA	NA	2	6
Price per pound, commercial grade	$1.61–$2.00	$3.00–$4.00	$4.00–$5.25	$6.00	$6.00	$6.00
World: Production	219	[r] 389	375	396	[r] 318	279

[r] Revised. NA: Not available.

Consumption and Uses.—Tellurium was consumed in the manufacture of free-machining steels, tellurium-copper alloys, ceramics, chemicals, thermoelectric devices, and in the rubber industry.

Stocks.—The stocks of tellurium at producers' plants has increased an average of 33,000 pounds annually since 1961, reaching 162,000 pounds in 1964, the highest since 1957.

Prices.—Commercial-grade tellurium (99.7 percent) was quoted at $6 per pound for the entire year. The 99.99-percent grade was quoted at yearend at $11 to $15 per pound, and the 99.999-percent grade at $21 to $30 per pound, depending on quality.

Foreign Trade.—Imports for consumption of tellurium unwrought metal, waste, scrap, and compounds totaled 6,222 pounds, valued at $44,400; of this quantity Canada supplied 6,000 pounds, Peru 220 pounds, and the United Kingdom 1 pound of unwrought metal, waste, and scrap. The United Kingdom also supplied 1 pound of tellurium compounds.

World Review.—World production of tellurium was 12 percent less than in 1963 and 30 percent less than in the record year of 1962.

Canada.—Production of tellurium increased 4 percent over that of 1963. The International Nickel Company of Canada, Ltd., Copper Cliff, Ontario; and Canadian Copper Refiners, Ltd., Montreal East, Quebec, recovered tellurium from anode slimes produced during electrolytic refining of copper.

Japan.—Output of tellurium declined 43 percent in 1964 compared with 1963. The Osaka refinery, Mitsubishi Metal Mining Co., Ltd.; the Takehara refinery, Mitsui Mining & Smelting Co., Ltd.; and the Hitachi and Saganoseki refineries of the Nippon Mining Co., Ltd., produced tellurium.

Peru.—Tellurium production increased about 76 percent over that of 1963. The Oroya refinery of the Cerro de Pasco Corp. produced tellurium.

TABLE 10.—Free world production of tellurium by countries[1]

(Pounds)

Country	1955–59 (average)	1960	1961	1962	1963	1964 p
North America:						
Canada	19,936	44,682	77,609	58,725	76,842	79,789
United States	182,495	271,000	205,000	264,000	201,000	145,000
South America: Peru	15,979	59,343	76,279	50,472	26,634	46,757
Asia: Japan	982	13,671	16,486	23,168	13,256	7,573
Free world total[1]	219,400	388,700	375,400	396,400	317,700	279,100

p Preliminary.

[1] This table incorporates a number of revisions of data published in previous Tellurium chapters. Data do not add exactly to totals shown because of rounding.

Technology.—The AIME published reports on preparation of fine-grained PbTe using ultrasonic agitation,[9] and single-phase AgSbTe by zone-melting techniques;[10] investigation of some of the electrical properties of alloys of PbTe-SnTe,[11] and the crystal chemistry of solid solutions of CdTe and InTe in PbTe and SnTe.[12]

A congruently melting compound, $AgIn_3Te_5$, consisting of 25 mole percent Ag_2Te and 75 mole percent In_2Te_3 was produced by zone refining. The telluride has a melting point of 699°±3° C. The report on the telluride gave data on electrical conductivity, Hall effect, Seebeck coefficient, and thermal conductivity above room temperature.[13]

A method was developed for joining Bi_2Te_3 thermoelements to copper plates which gave a mechanically strong bond with a low contact resistance.[14] The Bi_2Te_3 elements were sandblasted and rhodium plated prior to application of indium-tin solder to hold on the copper plates.

Patents were issued on the manufacture of a glass containing a maximum of 70 atomic percent tellurium,[15] and on the production of high-purity tellurium.[16]

The Bureau of Mines published results of an investigation of tellurium resources in Arizona, Colorado, New Mexico, Utah, and at the Bambolla mine near Moctezuma, Sonora, Mexico;[17] and a report of investigation on methods for determining selenium and tellurium in complex oilfield brines.[18]

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[9] Weinstein, Martin. Preparation of Fine-Grained PbTe by Ultrasonic Agitation of a Solidifying Melt. Trans. Met. Soc. AIME, v. 230, No. 2, March 1964, pp. 321–328.

[10] Burmeister, R. A., and D. A. Stevenson. Preparation and Electrical Properties of Silver Antimony Telluride. Trans. Met. Soc. AIME, v. 230, No. 2, March 1964, pp. 329–332.

[11] Machonis, Alvin A., and Irving B. Cadoff. Investigation of Alloys of the System PbTe-SnTe. Trans. Met. Soc. AIME, v. 230, No. 2, March 1964, pp. 333–339.

[12] Rosenberg, Arthur J., Robert Greirson, J. C. Woolley, and P. Nikolic. Solid Solutions of CdTe and InTe in PbTe and SnTe. Trans. Met. Soc. AIME, v. 230, No. 2, March 1964, pp. 342–350.

[13] O'Kane, Daniel F., and Donald R. Mason. Semi-Conducting Properties of $AgIn_3Te_5$. J. Electrochem. Soc., v. 111, No. 5, May 1964, pp. 546–549.

[14] Nanda, M. M. Joining Techniques for Bi_2Te_3 Elements in Thermoelectric Cooling Devices. Electrochem. Technol. v. 2, No. 5–6, May–June 1964, pp. 134–137.

[15] Bailey, Louis H., Maurice J. Brau, and Albert R. Hilton (assigned to Texas Instruments Inc., Dallas, Tex.). Glass and Method of Making It. U.S. Pat. 3,154,424, Oct. 27, 1964.

[16] Champ, Roger (assigned to La Société les Produits Semi-Conducteurs, Paris, France). Production of Tellurium. U.S. Pat. 3,158,443, Nov. 24, 1964.

[17] Everett, F. D. Reconnaissance of Tellurium Resources in Arizona, Colorado, New Mexico, and Utah; Including Selected Data from Other Western States and Mexico. BuMines Rept. of Inv. 6350, 1964, 38 pp.

[18] Collins, R. Gene, Cathy J. Waters, and Cynthia A. Pearson. Methods of Analyzing Oilfield Waters; Selenium and Tellurium. BuMines Rept. of Inv. 6474, 1964, 19 pp.

THALLIUM[19]

Domestic Production.—American Smelting and Refining Company at Denver, Colo., was the only domestic producer of thallium. This firm produced more, consumed more, and shipped less of the metal than in 1963. The company's thallium sulfate production and shipments were larger than in 1963.

Uses.—The largest use of thallium was as the sulfate, a poisonous rodenticide and insecticide. Thallium has a significant use in electronics, such as for thallium-activated sodium iodide crystals in photomultiplier tubes. Other uses of thallium were in low-melting alloys, in optical glass, and in glass seals for the protection of electronic components.

Price.—The price of thallium metal was $7.50 per pound.

Technology.—The Lamp Division of Westinghouse Electric Corp. announced development of a new mercury lamp containing additions of thallium, sodium, and iodine. The new lamp yields a yellowish-white light in contrast to the blue-green of the normal mercury lamp, has a long service life, and produces 90 lumens per watt compared with 54 lumens for an ordinary 400-watt mercury lamp.[20]

Properties of glasses, including the arsenic-sulfur-thallium and the arsenic-selenium-thallium systems, were investigated. In the latter system, compositions relatively high in thallium and low in selenium had unusually low electrical resistivities for glasses representative of semiconductor material.[21]

WOLLASTONITE[22]

Wollastonite sales, 9 percent greater in volume in 1964 and 13 percent higher in value than in 1963, were made principally to manufacturers of ceramics, paint, fiber glass, and wall board. Nearly all of the high-quality wollastonite for these applications was supplied by Cabot Minerals Division of Cabot Corp. from their Willsboro mine in Essex County, N.Y., although a small quantity was mined near Lewis, N.Y., by Adirondack Development Corp. for market study and experimental purposes. Two California companies quarried wollastonite for use as ornamental building stone.

Prices for wollastonite quoted by Oil, Paint and Drug Reporter in 1964 (unchanged from 1963) were as follows: Fine, paint-grade, bags, carlots, works, $41 per ton; less than carlots, $51 per ton; medium, paint-grade, bags, carlots, works, $29 per ton; less than carlots, ex-warehouse, $39 per ton.

A small amount of wollastonite was mined in South-West Africa, and it was reported that exploitation had been started of wollastonite deposits near Motueka in New Zealand.[23]

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[19] Prepared by Harold J. Schroeder.

[20] Electrochemical Technology. V. 2, No. 5–6, May–June 1964, p. 179.

[21] Pearson, David A. Preparation of Sulfide, Selenide, and Telluride Glasses. The Glass Industry, v. 45, No. 12, December 1964, pp. 666–669, 712–713.

[22] Prepared by J. Robert Wells.

[23] Mining Magazine (London). Current Exploration in New Zealand. V. 111, No. 6, December 1964, p. 425.

Technology.—Publication was made of the results of research on the detailed crystal structure of wollastonite and related minerals of the pyroxene group.[24]

A discussion of the advantages of wollastonite glazes for sanitary ware was published,[25] and wollastonites from two California deposits were studied with a view to their possible application in ceramics.[26]

A patent was granted on the use of wollastonite with zinc oxide and other ingredients in the making of electrically conductive ceramic tile for hospital floors to reduce the danger of ether explosions from sparks of static electricity in operating rooms.[27]

Wollastonite constitutes about 30 percent of a patented composition for producing a lightweight foamed insulation material without the application of external heat [28] and 30 to 80 percent of a composition for coating electrodes for submerged arc welding.[29]

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[24] Prewitt, C. T., and Donald R. Peacor. Crystal Chemistry of the Pyroxenes and Pyroxenoids. Am. Mineralogist, v. 49, Nos. 11–12, November–December 1964, pp. 1527–1542.

[25] Jackson, William. Status of Wollastonite Glazes for Sanitary Ware. Ceram. News, v. 13, No. 4, April 1964, pp. 15–16.

[26] Neely, J. R., and W. J. Knapp. California Wollastonites. Ceram. News, v. 13, No. 5, May 1964, pp. 12–13.

[27] Greger, H. H., and D. F. Greger. Electrically Conductive Ceramic Tile. U.S. Pat. 3,121,065, Feb. 11, 1964.

[28] Vukasovich, M. S., and H. L. Johns (assigned to Horizons, Inc., a corporation of New Jersey). Foamed Ceramic. U.S. Pat. 3,148,996, Sept. 15, 1964.

[29] Assigned to Hitachi, Ltd. Japanese Pat. 1325 (1964), Feb. 12, 1964.

INDEX

The index consists of two parts: A commodity index and a company index. Because nearly all commodity chapters in Minerals Yearbook, volume I, follow a standard outline (Introductory Summary, Domestic Production, Consumption and Uses, Stocks, Prices (and specifications), Foreign Trade, World Review, World Reserves, and Technology), references to such data have been omitted under the various headings.

Readers seeking information on mine production for States, territories, or possessions should refer to tables in the Statistical Summary chapter, starting on page 105. These tables show the commodities produced in each area, thus guiding the reader to the appropriate commodity chapters. For complete area information, however, the reader should refer to volume III.

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